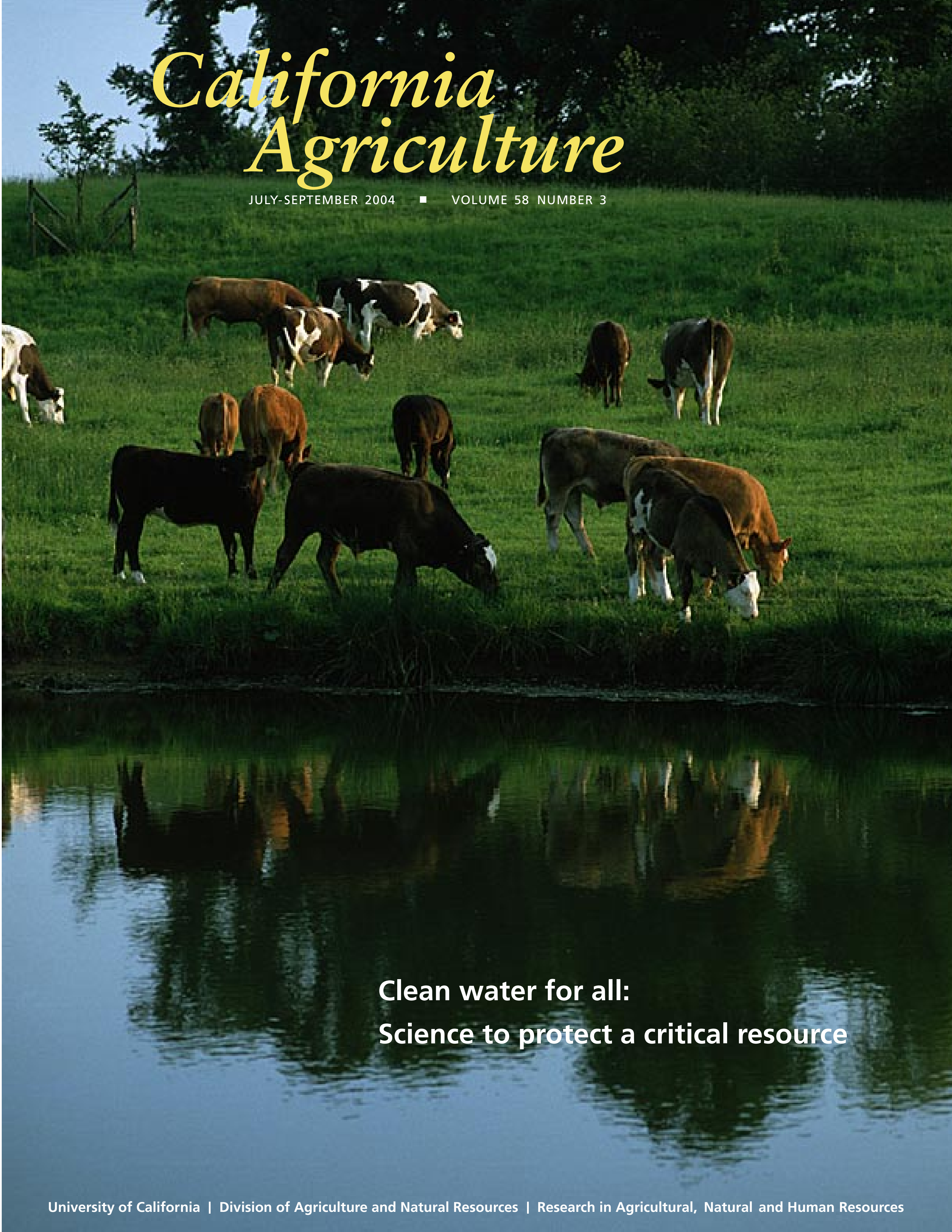
California Agriculture

JULY-SEPTEMBER 2004 ■ VOLUME 58 NUMBER 3



Clean water for all:
Science to protect a critical resource

Water quality key to state's prosperity

Barbara Allen-Diaz
Professor
Rangeland Ecology and Management,
UC Berkeley

William E. Frost
Program Leader
Natural Resources, Agriculture and Natural Resources

Prosperity in California has always depended on the effective management of limited water supplies. Today that management is more critical than ever, as the state prepares for unprecedented population growth yet seeks to maintain agricultural productivity, wildlife and aquatic habitats, and ecological integrity.

Early in the 1900s, during another period of rapid growth, Californians constructed dams to provide a greater, more reliable water supply. Managers gave little thought to the ecological consequences of their actions, altering flow regimes and destroying some ecosystems. They conducted widespread drainage of wetlands without fully considering the contributions of these aquatic and estuarine ecosystems to water and air purification and biodiversity.

Today, "there is a massive environmental debt to repay in California, which is reflected in the degraded nature of so many of our streams, lakes and estuaries," wrote UC Davis biologist Peter Moyle in the March-April 2000 *California Agriculture*. "We can fix things now, or we can wait until conditions get worse and we experience even more strongly the loss of benefits provided by healthy ecosystems."

"Fixing" aquatic ecosystems does not require the re-creation of a pristine environment from the past, Moyle noted. It means re-establishing a balance in ecosystem structure and function to meet the needs of plants, animals and humans while maintaining a region's diverse and vibrant economy. In one recent example of such re-establishment, UC Agriculture and Natural Resources (ANR) scientists have spearheaded education and research programs to improve water quality across the grazed rangeland ecosystems of California.

California rangelands provide forage for cattle and calves, the state's 4th-largest agricultural commodity valued at $1.75 billion in 2002. Rangelands occupy about 57 million of our 101 million acres statewide. Of these, 24 million (42%), are privately owned and provide 90% of the state's cattle forage.

The major drainage basins of the state are largely comprised of rangeland. While rangelands only intercept about 15% of the precipitation in the state, almost all surface water in California passes through them. Approximately 9,000 miles of streams and 125,000 acres of wetlands associated with springs, wet meadows and vernal pools occur within California rangelands.

Poorly managed livestock grazing can affect California's water quality by reducing vegetation cover, potentially changing wetland/riparian species composition, and increasing temperature, sediment, nutrients and pathogens in waterways. Livestock can physically impact California waters through their hoof-action, compacting wetland areas and breaking down stream banks. Many scientists and regulators consider grazing a potential nonpoint source of pollution on rangelands. However, recent studies have also shown that proper grazing management can provide benefits; for example, well-managed grazing near vernal pools had the beneficial effect of promoting native vegetation.

In 1990, leaders in the livestock industry initiated an effort with the state's Range Management Advisory Committee (RMAC) and the State Water Resources Control Board (SWRCB) to develop a nonpoint source pollution control plan for nonfederal rangelands. At the same time, UC Cooperative Extension (UCCE) established the Rangeland Watershed Program with the USDA Natural Resources Conservation Service, addressing these issues through education, technical assistance and research. The California Rangeland Water Quality Management Plan (CRWQMP) was approved by RMAC and SWRCB in 1995.

This comprehensive plan directs rangeland owners and managers to voluntarily develop and implement ranch water-quality plans for their private land, helping them fulfill statutory requirements of the Clean Water Acts of 1977 and 1994, and the Porter-Cologne Act of 1969. By 1997, UCCE had developed and begun delivering the Ranch Water Quality Planning Shortcourse to enable landowners and managers to voluntarily comply with the plan (see page 134). Since 1997, more than 400 ranch water-quality plans have been developed covering 1.3 million acres of rangeland. UCCE is now expanding delivery of the course to farmers along the Central Coast.

The course is based upon the best scientific information available. During its implementation many questions were raised for which there were no research-based answers. These questions stimulated collaborations between campus-based faculty and UCCE specialists and advisors. One such collaboration showed that livestock-induced, nonpoint pollution can be reduced if sufficient vegetation is left in the uplands in riparian areas and along stream banks, and if livestock are not allowed to concentrate in riparian areas and along streams. Other projects demonstrated the value of residual dry matter in reducing sediment movement; the relationship of grazing management practices and water quality in springs; the origin and movement of pathogens from livestock and wildlife into waterways; and the effectiveness of vegetative buffer strips in filtering sediment, nutrients and pathogens. Several articles in this issue report on research aimed at preserving the state's critical aquatic resources (see pages 138 to 163).

If California is to ensure the availability of high-quality water, we must augment the kind of integrated research and extension efforts that fostered the successful ranch water-quality plans. Research must employ ecological, economic and social approaches, in addition to engineering, to solve water problems.

By examining the diverse biological, physical and socio-economic components of the water-quality issue, we can provide reliable information to help managers make the decisions that will ensure California's future.

California Agriculture

News and Peer-reviewed Research published by the Division of Agriculture and Natural Resources, University of California

VOLUME 58, NUMBER 3

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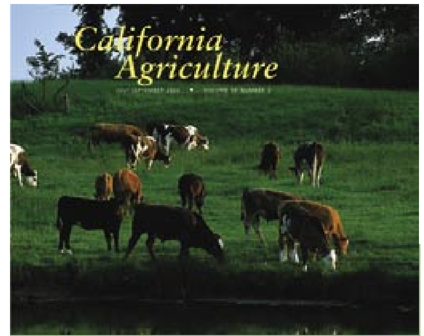
California Agriculture (ISSN 0008-0845) is published quarterly and mailed at periodicals postage rates at Oakland, CA and additional mailing offices. Postmaster: Send change of address "Form 3579" to California Agriculture at the above address.

RATES: Subscriptions free upon request in U.S.; $24/year outside the U.S. After publication, the single copy price is $5.00. Orders must be accompanied by payment. Payment may be by check or international money order in U.S. funds payable to UC Regents. MasterCard/Visa accepted; requests require signature and card expiration date. Please include complete address.

News departments



Corbis

Cover: Almost all of California's surface water passes through the state's 57 million acres of rangeland. Ranch water-quality plans are aimed at limiting levels of sediment, pathogens, heat build-up and nutrients in streams. Careful management, informed by state-of-the-art science, can minimize nonpoint source pollution attributed to cattle grazing (see pages 134, 138 and 144).

Research articles

Focus on water quality

Editor's note:
Due to cutbacks related to the state's budget deficit, *California Agriculture* will be publishing four issues in 2004 instead of six.

Letters

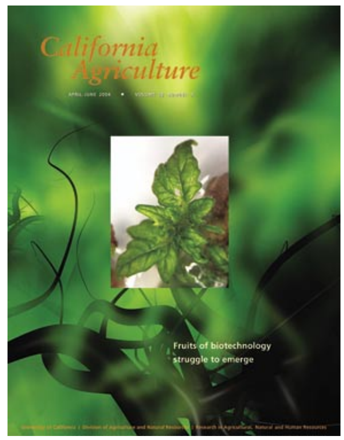
WHAT DO YOU THINK?
The editorial staff of *California Agriculture* welcomes your letters, comments and suggestions. Please write to us at calag@ucop.edu or 1111 Franklin St., 6th fl., Oakland, CA 94607. Include your full name and address. Letters may be edited for space and clarity.

High-quality social analysis

I enjoyed reading "Horticultural biotechnology faces significant economic and market barriers," in April-June 2004 *California Agriculture*. Author Julian Alston deals with the behavior of people and their institutions in a way that is analogous to how I deal with plants' regulatory pathways. It is an interesting contrast in that among physiologists like me and many other plant scientists, the subject quickly becomes a blame-fest accusing various players of being stupid, dishonest, selfish or greedy. In contrast, the article approaches all of these people factors as behaving just as neutrally as plant pathways. They just do what they do, and these are the consequences. At the end, some reasonable predictions are made about which changes in the system would result in greater adoption of horticultural biotechnology.

How does one get biologists to apply their honed skills at unprejudiced analysis to human systems? Since this analysis is familiar in its scientific approach but differs in subject matter, it provides the best teaching tool I have seen for raising the quality of social analysis by biological scientists dealing with horticultural biotechnology.

Thomas Björkman
Associate Professor of Vegetable Crop Physiology
Cornell University
Biochemistry, UC Davis, 1980



April-June 2004 issue

Outstanding review

Thank you for publishing the outstanding review of horticultural biotechnology in your latest issue of California Agriculture. It is packed with well-written articles and useful information.

Daniel Pollak
California Research Bureau
Sacramento

Ecological risks ignored

I am appalled by your recent issue (April-June 2004) on biotechnology. There is not one article on the potential ecological risks of genetically modified organisms (GMOs). In my opinion this is a disservice to the farmers and consumers of California, as your magazine provides a one-sided view on an important issue. I challenge you to consider inviting a paper on the risks of this technology and the alternatives available.

Miguel A. Altieri
Professor of Agroecology
UC Berkeley

Editor's response: We are already at work on a special section devoted to the risks and benefits of agricultural biotechnology (see the Editor's note at the top of the first text page of the April-June 2004 issue). The peer-reviewed manuscripts of that issue examined the hurdles to horticultural biotechnology only. In our judgment, a careful examination of risks and benefits also merits a special section.

Correction on GE cotton in California

The photo caption on page 95 of the April-June 2004 issue mentions that Bt cotton is widely grown in California and elsewhere. The "elsewhere" part is indeed true, but Bt cotton is not grown to any great extent in California. We simply do not have most of the Lepidoptera pests in California cotton that Bt controls. Statewide, only 7,400 acres of Bt cotton were grown in California out of the 2003 total of 691,930 acres, primarily in the Imperial Valley for pink bollworm control. In the San Joaquin Valley where most of the cotton is grown, there is virtually no Bt cotton grown.

Pink bollworm is managed in the San Joaquin Valley by the Cooperative Pink Bollworm Program, which is funded almost entirely by cotton growers and operated by the California Department of Food and Agriculture. The program uses an integrated pest-control approach, relying on trapping, sterile release, crop destruction and occasional pheromone treatments to keep infestations below economic impact levels. There may be some acres of it grown because the Bt technology was combined — so called stacked — with glyphosate-resistant (Roundup Ready) cotton, which is very common and important in California, but if so it clearly is not grown because of the Bt trait.

Larry D. Godfrey
Extension Entomologist
UC Davis

Sudden oak death genome mapped

The entire DNA blueprint for *Phytophtora ramorum* — the pathogen that causes sudden oak death — has been sequenced, scientists with the Joint Genome Institute (JGI) announced in June. The nonprofit institute is operated by UC for the U.S. Department of Energy.

Mature oak trees began mysteriously dying from sudden oak death in the mid-1990s; UC scientists identified and diagnosed *P. ramorum* as the culprit in 2000. JGI scientists, who collaborated with the Virginia Bioinformatics Institute, announced that *P. ramorum* has 16,000 genes and 60 million chemical DNA units (base pairs). (Humans have 25,000 to 30,000 genes and 2.9 billion base pairs.)

Concurrently, JGI announced the sequencing of *Phythophthora sojae*, which causes root rot in soybeans. The genome sequences are expected to help scientists develop rapid detection systems and methods to control the spread of sudden oak death, which has killed tens of thousands of trees, and the soybean disease, which causes an estimated $1 billion in crop losses annually.

As of June, *P. ramorum* had been found in 13 California counties and southern Oregon, as well as 125 nurseries in 17 states nationwide. In April, wood rose *(Rosa gymnocarpa)*, a native California flower commonly found in a variety of habitats and a popular ornamental, was added to the list of about 30 regulated *P. ramorum* host plants.

Courtesy of Matteo Garbelotto

Phytophtora ramorum, **the pathogen that causes sudden oak death.**

No safe place to sit in tick-infested forests

Resting on a log or leaning against a tree in California's tick-infested hardwood forests can increase the risk of acquiring ticks harboring the Lyme disease bacterium, UC Berkeley researchers found.

"We sat on logs for only five minutes at a time, and in 30% of the cases, it resulted in exposure to ticks," said Insect Biology professor Robert Lane. "The next riskiest behavior was gathering wood, followed by sitting against trees, which resulted in tick exposure 23% and 17% of the time."

The study, published in the March *Journal of Medical Entomology,* is the first quantitative analysis of human behaviors that may increase the risk of tick exposure in California's hardwood forests. Lane and study co-author Denise Steinlein, a UC Berkeley graduate student in insect biology, conducted the research at the UC Hopland Research and Extension Center in southeastern Mendocino County. UC Berkeley research specialist Jeomhee Mun is also a co-author.

The western black-legged tick, found primarily in the far western United States as well as British Columbia, is the primary carrier of the corkscrew-shaped spirochete *Borrelia burgdorferi,* which is responsible for Lyme disease (see *California Agriculture* 55[6]:13–8). The young nymphal ticks that generally spread Lyme disease are notoriously difficult to detect. California's nymphal tick season begins in early spring and continues into summer.

DNA tests revealed that 3% to 4% of the ticks the researchers found on their bodies, as well as by sampling leaf litter with a white flannel cloth, tested positive for *B. burgdorferi* and another, less prevalent human disease-causing bacterium, *Anaplasma phagocytophilum*.

Photos: Robert Lane

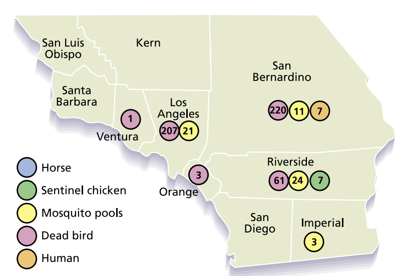
The researchers wore white clothing from head to toe, and engaged in a series of typical outdoor activities to attract ticks, such as sitting on logs and leaning against trees. *Top,* Denise Steinlein carries wood at the tick-infested UC Hopland Research and Extension Center. *Bottom,* the nymphal stage of the western black-legged tick, which can carry the spirochete that causes Lyme disease, is the size of a poppy seed.

West Nile virus spreads

As of June 22, California health officials had confirmed seven human cases of West Nile virus (WNV) in 2004, including a 61-year-old San Bernardino County man hospitalized with encephalitis. The virus, which is transmitted from birds to mosquitoes to humans (or horses), has also been confirmed in nearly 500 dead birds in Los Angeles, Riverside, San Bernardino and Ventura counties.

"What the dead birds are telling us is that there's a lot of virus circulating out there," says John Edman, director of the UC Davis Center for Vectorborne Diseases (UCD/CVB). "We're in a high state of alert."

UC Davis scientists are collaborating with the California Department of Health Services, California Department of Food



As of June 22, 2004, California's surveillance network had detected West Nile virus in humans; dead birds; aggregate pools of mosquitoes; and sentinel chickens, which have their blood drawn and tested biweekly. No infected horses have been found. Source: www.westnile.ca.gov

and Agriculture, local mosquito and vector control districts, and other agencies on a statewide surveillance program for WNV. The UCD/CVB biocontainment laboratory tests tissues from all reported dead birds, blood from sentinel chickens (in 232 flocks of 10 each), and pools of 50 mosquitoes each gathered from nearly 3,000 traps around the state (see figure, page 133).

The risk of serious illness from WNV in humans is low, with the elderly, the young and those with compromised immune systems at greatest risk. While most infected individuals will not experience any illness or only mild symptoms, some of those infected will develop serious neurological symptoms such as encephalitis or meningitis. In 2003, 9,862 WNV cases were reported to the U.S. Centers for Disease Control nationwide, with 264 deaths.

Statewide, the UC Division of Agriculture and Natural Resources funds the Mosquito Research Program, which provides grant support for UC research projects that investigate the vectors of WNV and other mosquito-borne diseases and seek environmentally safe methods to improve mosquito management. Likewise, about 40 members of the UC Mosquito Research and Extension Workgroup are working together to establish research priorities and seek extramural funding to pursue additional WNV-related research. *— Editors*

(*As we went to press, the number of human cases in California continued to climb, totalling 17 on July 10.*)

Outreach news

John M. Harper

Water-quality short course participants evaluate a sediment source site (bank-cutting) along Parson's Creek using the Sediment Inventory Method, at the UC Hopland Research and Extension Center in Mendocino County.

Courses help ranchers, farmers mitigate water-quality impacts

Most of the water-quality problems in the United States are from runoff, and in many places much of this nonpoint source pollution in rivers and lakes comes from agriculture, according to the U.S. Environmental Protection Agency (EPA). Ranching and farming practices can degrade streams and coastal waters with nonpoint source pollutants such as sediment, heat and nutrients (see pages 138 to 163). This degradation can threaten salmon, which need cold, clear water for spawning.

In 1989, the range livestock industry recognized that it needed to address water quality and asked UC for help. "The industry knew regulation was coming," says Melvin George, UC Cooperative Extension (UCCE) rangeland management specialist.

In 1994, the UCCE Rangeland Watershed Program began working with ranchers and state agencies to develop the Ranch Water Quality Management Planning Shortcourse, which helps ranchers develop voluntary plans for managing water quality on their land. "The beauty of it is that landowners can make their own decisions so they don't have a regulatory agency come and tell them what to do," says George, who helped develop the short course.

Landowners in watersheds with rivers listed as impaired by the EPA must help meet total maximum daily load (TMDL) regulations, which stipulate how much pollution bodies of water can receive and still meet water-quality standards.

The ranch water-quality short course entails about 10 to 15 hours of classroom and field instruction, including clean water laws; monitoring pollution sources; and management of nonpoint source pollution, such as sediment from cattle grazing and trampling, heat from decreased riparian vegetation, and nutrients and pathogens from manure. The short course culminates in developing individualized ranch water-quality management plans that identify and prioritize water-quality problems and outline how to address them.

The short course has had more than 60 sessions attended by more than 800 ranchers from 31 counties, and by mid-2004 had resulted in plans covering 1.3 million acres of rangeland. A 2002 survey of participants showed that 60% had completed a plan in class and 67% had implemented at least one

John M. Harper

Road crossings at streams are an important source of potential sediment on North Coast rangelands.

of the recommended practices for protecting water quality. These practices include installing fences to exclude cattle from riparian areas; revegetating riparian areas; and slowing down the movement of water along and across dirt roads, which are a major source of sediment on slopes. "We proved that a voluntary program can work," George says.

The short course also encourages landowners to form watershed management groups. "Nonpoint source pollution is not an individual problem, it's a watershed problem. If everyone gets together, they can have an effect," George says. Course participants have formed watershed groups in counties including Humboldt, Mendocino and Monterey. Other benefits of forming such groups are that they are more likely to get water-quality grants and can streamline permitting for watershed activities such as modifying streambeds.

A similar course for Central Coast farmers was patterned on the successful ranch course a few years ago, spearheaded by UCCE farm advisor Mary Bianchi. Unlike many other irrigated agricultural areas in California, many Central Coast farms are on slopes that are susceptible to erosion. Moreover, these watersheds drain into Monterey and Morro Bay estuaries or into rivers where salmon spawn.

This new course for farmers may be particularly relevant to growers in coming years. While agricultural discharges in California have historically been exempt from water-quality regulations, the State Water Resources Control Board recently began developing a compliance process for growers who discharge irrigation return water. The process would include monitoring and management measures to protect downstream water resources.

Like the ranch short course, the Farm Water Quality Management Planning Shortcourse culminates in developing a water-quality management plan that addresses farm nonpoint source pollution such as sediment, nutrients and pesticides. The short course is now offered in all seven Central Coast counties from San Mateo to Santa Barbara, and already 16% of the Central Coast producers have participated (about 400 out of 2,500). The course is offered in both English and Spanish, and binder materials will soon be available in Spanish.

"[The short course] encourages growers to complete conservation plans that integrate their production goals and management practices with water quality, habitat conservation and soil conservation goals," says Julie Fallon, representative for the UCCE Farm Water Quality Planning Program.

— Robin Meadows

Dairy workers learn husbandry, management skills

While California is the top milk-producing state nationwide, many workers in the state's 2,125 dairies lack basic husbandry skills. In addition, as dairies have gotten larger, the dairy herdsman's role has grown to include training and managing other employees. "California dairies are getting so intricate that employees need state-of-the-art training," says Gerald Higginbotham, UC Cooperative Extension (UCCE) dairy advisor.

To help meet this need, UCCE dairy advisors and specialists established the Dairy Herdsman Shortcourse. Higginbotham coordinates the program, which was developed with input from the California State University (Fresno and Chico), UC School

Students in UC Cooperative Extension's dairy herdsmen short course receive state-of-the art training in basic husbandry and dairy herd management. Gerry Sanchez (with stethoscope) listens for the heart and lung sounds of a dairy cow at the California State University, Fresno, dairy farm.

UC Cooperative Extension dairy specialist Steven Berry discusses tools used in the proper care of cow hoofs.

of Veterinary Medicine, California Animal Health and Diagnostic Laboratory, and dairy producers. Five short courses have been held since 2001 for about 170 dairy employees.

The Dairy Herdsman Shortcourse spans 3 days, with lectures in the mornings and hands-on laboratories in the afternoons. Because many Western dairy workers are Latino, the short course presentations are simultaneously translated into Spanish. Participants receive a notebook with the lectures and presentations, a California Mastitis Kit, a stethoscope and one colostrometer per dairy.

The short course covers dairy management, basic dairy husbandry and the latest in dairy practices. The management sessions include the use of herd-management software as well as labor management, from selecting to evaluating and disciplining employees.

The husbandry lectures include reproductive anatomy; milking and troubleshooting milk-quality problems; and herd health, such as nutrition and diagnosing diseases like mastitis and Johne's disease. The husbandry labs include assessing cow health from heart and lung sounds, proper hoof trimming and a calf autopsy. The most recent short course also had a lab on difficult calvings, in which participants learned how to manipulate calves into a normal position.

The sessions on the latest in dairy practices include educating herd managers on animal welfare issues related to tail docking (clipping) and handling downer cows. While some dairymen think docking leads to cleaner udders and cleaner milk, science does not support this practice. "It was a fad several years ago," says UCCE veterinarian John Kirk, who helps teach the short course. However, research has shown that docking fails to increase udder cleanliness or reduce the milk bacteria count. Moreover, docking has a downside for cows, which need their tails to brush away flies. "We focus on the welfare of cows," Kirk says.

Downer cows are those that are not ambulatory for reasons such as nerve damage during calving. Fears of bovine spongiform encephalopathy (BSE, "mad cow disease") have led to a ban on taking downer cows to the slaughterhouse. Instead, they must be euthanized at the dairy and picked up by a renderer. The short course teaches several methods for euthanizing cows. "If a downer cow doesn't recover in a couple of days, they should be euthanized to reduce suffering," Kirk says.

The effectiveness of the short course has been demonstrated in two ways. First, more than 70% of participants get higher scores on the posttest than on the pretest of the material covered. Second, a survey of participants in the first three courses showed that more than 40% have already begun to apply what they learned to their dairies.

The Dairy Herdsman Shortcourse is in such demand that there is a waiting list to participate. The course is particularly beneficial to counties that no longer have dairy advisors due to state budget cuts, such as Stanislaus, San Joaquin and even Tulare, which is the state's top dairy county. "We're trying to fill those voids by taking this program on the road," Higginbotham says. — *Robin Meadows*

Short course information

Ranch water quality

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Johne's disease

John Kirk
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Preventing Johne's disease is good all-around dairy practice

About one-fifth of U.S. dairies have cows with Johne's disease, but in 1997 nearly half of the nation's dairy producers were unaware of this bacterial illness, which can cause chronic diarrhea, wasting and ultimately cattle death. California dairy workers who have participated in a voluntary educational program on controlling Johne's ("Yo-knees") disease are both more aware of this illness and more likely to do something about it, according to a 2003 survey of participants by John Kirk, UC Cooperative Extension (UCCE) veterinarian.

Also called paratuberculosis because it is caused by the slow-growing bacterium *Myobacterium avium paratuberculosis* (Map), Johne's disease primarily affects the digestive systems of cows and other ruminant animals. The disease can decrease milk production, and increase mastitis and reproductive disorders. Afflicted cows usually catch the disease as newborn calves via manure, colostrum or milk but have no symptoms until they are at least 3 years old.

Because California dairies generally do not keep cows long enough for the disease to manifest, it has little apparent economic impact on them. Even so, controlling the disease is in the dairy industry's best interests. Johne's disease is somewhat similar to the human Crohn's disease, a chronic inflammatory bowel disease that likewise causes chronic diarrhea and weight loss, and has no cure. While the cause of Crohn's disease is unknown, some fear that people can catch it by drinking cow's milk.

Studies to date have yielded conflicting results and there is not enough evidence to prove or disprove a link between the two diseases, according to a 2003 National Academies of Science report. "It seems biologically plausible that Map could cause at least a subset of Crohn's disease," the report stated. "If evidence of a link were found, it would transform Johne's disease into a serious public-health problem." At this time, Johne's is considered a cattle disease and Crohn's a human disease.

To help control the disease, in 1999 the California Johne's Disease Advisory Council established a 1-hour educational program as part of the California Dairy Quality Assurance Program. Initially presented by UC Davis Veterinary Medicine Extension faculty, the Johne's disease educational program is now also presented by 150 certified private-practice veterinarians.

A followup survey of 27 participants showed that many have begun implementing measures for controlling Johne's disease. For example, the survey found that 92% are now looking for cows with symptoms of the disease; 86% are cleaning calving areas more frequently; and 60% are removing calves from the calving area before they begin to nurse. These measures are important because in most cases calves are infected soon after birth by ingesting manure or nursing from manure-covered teats.

Cows with advanced Johne's disease, a chronic wasting disease transmitted by manure, usually do not show symptoms until they are at least 3 years old. Signs of Johne's disease include chronic diarrhea and weight loss. Typically, affected animals remain bright and alert, without fever, and eating well.

However, some control measures were not as likely to be adopted. For example, while Johne's disease can also be transmitted in milk, more than half of the participants were doubtful about feeding calves pasteurized milk. This may be due to the high cost of effective pasteurization equipment, which ranges from $20,000 to $40,000. "Most dairymen have initiated control measures that require only a change in attitude or management without major costs," Kirk says.

In addition, the surveyed participants were split on using blood tests or fecal cultures to gauge the prevalence of Johne's disease in their herds. "This probably reflects the general feeling among California dairymen that this disease is of insignificant economic impact on their dairies," Kirk says.

"Bottle jaw," also called submandibular edema, is another sign of Johne's disease. A UC Cooperative Extension short course teaches dairy operators the clinical signs of Johne's disease, as well as how to prevent it.

However, measures to control Johne's disease can also benefit dairies by controlling other diseases. "Many dairy diseases are passed in manure or milk to newly born calves," says Kirk. "All Johne's disease control and prevention measures that reduce manure and milk transmission to calves will also reduce other diseases such as salmonellosis and mastitis."

— Robin Meadows

RESEARCH ARTICLE

Cattle grazing has varying impacts on stream-channel erosion in oak woodlands

Melvin R. George
Royce E. Larsen
Neil K. McDougald
Kenneth W. Tate
John D. Gerlach, Jr.
Kenneth O. Fulgham

There are 16 million acres of grazed rangeland in California's foothills. Much of the state's water flows through these areas and can be polluted with sediment from livestock grazing. Additional troughs and watering ponds can improve cattle distribution and protect water quality.

We conducted a 5-year study on the impact of grazing on stream-channel bare ground and erosion, and a 3-year study of cattle-trail erosion on intermittent stream channels draining grazed oak-woodland watersheds. While the concentration of cattle along stream banks during the dry season resulted in a significant increase in bare ground, we were unable to detect stream-bank erosion resulting from any of the grazing treatments applied. However, we did find that cattle trails are an important mode of sediment transport into stream channels. While cattle trails are common on grazed rangeland, excessive trailing often indicates that stock watering points are too far apart.

Most of California's surface water flows through the state's 16 million acres (6.4 million hectares) of annual rangelands in foothills. These foothill rangelands are drained by intermittent streams, which begin to flow following adequate rainfall during the October-to-May rainy season (Lewis et al. 2000). In dry years many intermittent streams in these rangelands do not flow. Sediment is a nonpoint source pollutant of concern in these surface waters.

Erosion and resulting sedimentation is a natural process that is often accelerated by human activities such as mining, construction, roads, timber harvest, crop production and livestock grazing. Excessive sedimentation clouds water, which reduces the amount of sunlight reaching aquatic plants; covers fish spawning areas and food supplies; and clogs the gills of fish. In addition, other pollutants such as phosphorus, pathogens and heavy metals are often attached to the soil particles and end up in downstream water bodies. Consequently, landowners and managers are planning and implementing erosion-control practices as part of regulatory requirements to reduce sediment loading in coastal streams and rivers (see page 134, 149). Because grazing is the dominant use of foothill rangelands it is frequently implicated as a source of sediment. However, Lewis et al. (2001) found that roads were a larger sediment source on ranches than grazing.

Improper livestock use can increase stream-bank erosion and sedimentation by changing, reducing or eliminating the vegetation that borders streams (Kaufman and Krueger 1984). Several studies have implicated livestock-induced stream-bank erosion, which leads to channel downcutting or widening (Kaufman and Krueger 1984; Hall and Bryant 1995; Sierra Nevada Ecosystem Project 1996).

In 1994, we began to monitor sediment delivery at the bottom of a 342-acre grazed oak-woodland watershed in Madera County. While not continuously grazed, this watershed was grazed several times each year, leaving 600 to 800 pounds of residual dry matter per acre in the fall, which meets UC guidelines (Bartolome et al. 2002).

We found that little sediment was suspended in water samples collected near the bottom of the watershed. On further investigation we found that most sediment moved along the bottom of the channel as bedload during storm runoff, increasing with flow and settling in low-gradient reaches of the stream channel (George et al. 2002). At this site, grazing management generally maintained adequate residual dry matter (Bartolome et al. 2002) on hill slopes; in addition, earlier studies by the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA/NRCS) had documented little overland flow and resulting surface erosion. Therefore, we suspected that the source of most of the bedload sediment was the stream channel and the adja-

Livestock grazing impacts, such as stream-channel erosion and impaired water quality, can often be addressed with management practices that alter livestock distribution on the landscape.

cent variable-source area that merges with the stream channel. We initiated two studies to determine the influence of grazing cattle on erosion in or near stream channels. The stream-channel study documented changes in stream-channel groundcover and stream-bank erosion due to different seasons and intensities of grazing. The cattle-trail study compared sediment movement on cattle trails and adjacent vegetated surfaces on the slopes of the variable-source area that merges with the stream channel. The purpose was to determine if cattle grazing and trampling contributed to the bedload sediment associated with intermittent stream channels in the central Sierra Nevada foothills.

San Joaquin Experimental Range

These studies were conducted on the San Joaquin Experimental Range (SJER) in Madera County in oak woodlands, which are dominated by coarse-loamy granitic soils of the Ahwahnee series (fig. 1). Numerous intermittent stream channels, most of which are tributaries to Cottonwood Creek, dissect the station. Cottonwood Creek is a fourth-order stream that drains into the San Joaquin River just below Friant Dam. During this study, stream flow began in early January following 11 to 14 inches (270 to 360 centimeters) of rainfall from October to December. While granite rocks, oak trees and other woody vegetation provide some stability, the majority of the stream banks are vegetated by shallow-rooted annual grasses and forbs. The stream bottoms are predominantly sand with some granitic cobble, rock and boulders. The channels are 2 to 10 feet wide, 1 to 3.3 feet deep and bedrock-controlled in many reaches. Three intermittent tributaries to Cottonwood Creek were selected for study at SJER. The study reaches (stream segments) are low-gradient with less than 2% slope and are Rosgen Class B5 (Rosgen 1996). Stream channels 1, 2 and 3 are 1 to 2 miles apart and at an elevation of 900 to 1,348 feet.

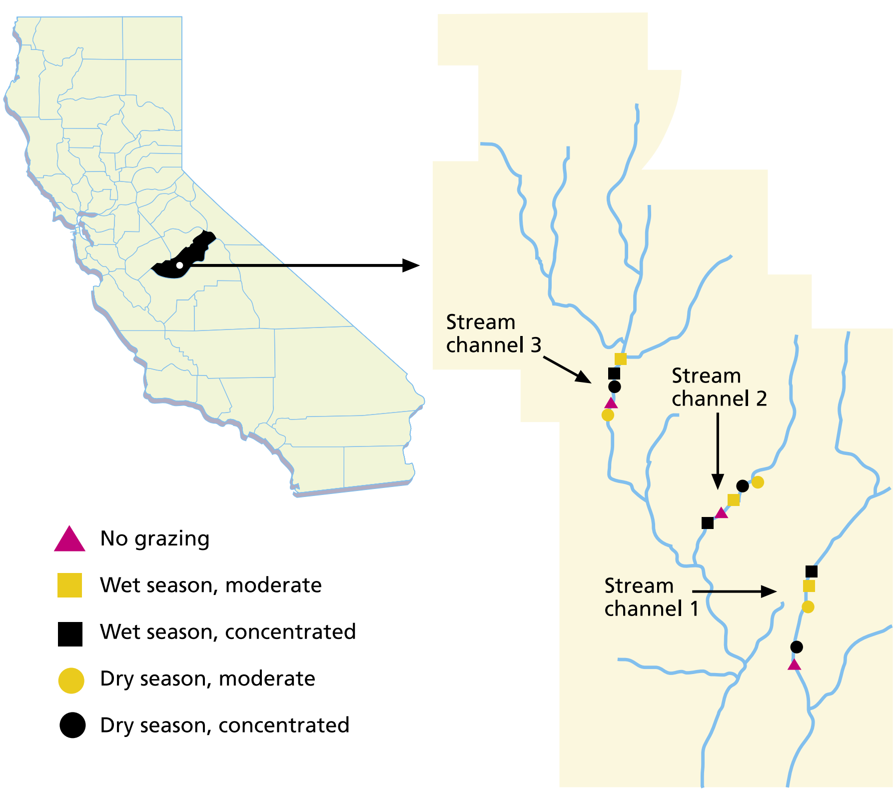


Fig. 1. Location of Madera County study site, and treatments along stream channels at the U.S. Forest Service San Joaquin Experimental Range.

Glossary

Animal unit: Often defined as a cow and her calf, or as a total of 1,000 pounds of body weight; **animal unit month:** amount of feed an animal unit will consume in 1 month.

Bankfull depth: Depth where channel is completely filled and water begins to spill onto adjacent floodplain.

Bedload: Heavier particles such as sand, gravel and rock that are too heavy to be suspended in the water column but that roll along the channel bottom during high flow events.

Channel bank: The often-steep component of a stream channel extending from the channel bottom to the top of the bank.

Nonpoint source pollution: Diffuse discharges of waste throughout the natural environment such as from mining, urban runoff, agriculture and logging.

Residual dry matter: Litter (old plant material) left standing or on the ground at the beginning of a new growing season (Bartolome et al. 2002).

Rosgen Stream Classification: A method of classifying stream channels based on channel gradient and confinement (Rosgen 1996).

Stock density: Number of animals per unit area at any point in time.

Stocking rate: The number of specific kinds and classes of animals grazing a unit of land for a specified time period.

Stream-channel down-cutting: Increase in channel depth due to erosion of channel bed.

Stream-channel widening: Increase in channel width due to erosion of stream banks.

Stream reach: Segment of a stream.

Undercut stream bank: A bank that has had its base cut away by the action of stream flow along natural overhangs in the stream.

Variable-source area: Runoff-generating saturated soils that vary in their extent with storm intensity and length.

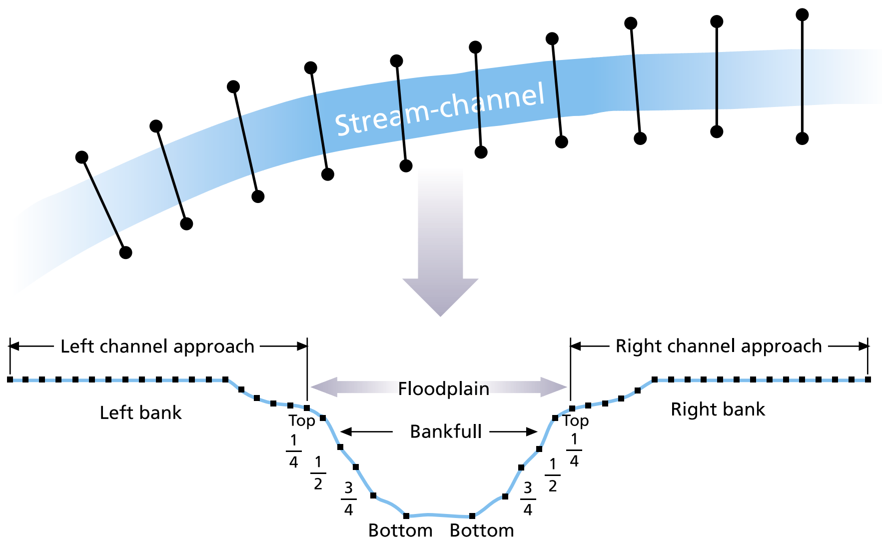


Fig. 2. Diagram of 10 stream-channel cross-section transects.

Grazing impacts on stream channels

Maintaining adequate vegetative groundcover is the first defense against soil erosion. Thus, decreasing groundcover or increasing bare ground is an indication of increasing risk of erosion. Increasing stream-channel width and depth are indicators of stream-channel erosion. The objective of our study on stream channels was to determine changes in bare ground along the channel banks and changes in channel width and depth in response to two seasons (wet and dry) and three grazing intensities (no grazing, moderate and concentrated).

Grazing treatments. Five grazing treatments were applied to five randomly selected 1-acre pastures established for a 5-year study along each of three intermittent streams (fig. 1). The treatments were:

- No grazing.
- Wet season, moderate grazing (stubble height = 2 to 3 inches).
- Wet season, concentrated grazing (stubble height < 2 inches).
- Dry season, moderate grazing (stubble height = 2 to 3 inches).
- Dry season, concentrated grazing (stubble height < 2 inches).

The concentrated grazing treatments were designed to apply the extremely heavy use often associated with a feed or watering site. Each grazing treatment was applied to the same pastures during 4 consecutive years.

Dry-season grazing treatments were applied between July 1 and Oct. 1, a period of little or no rainfall. Wet-season treatments were applied while the soil was moist and maintained until the end of the growing season. Typically, the wet season begins in late October or early November and ends by May 1. This period includes the slow winter growth period and all of the rapid spring growth period of the growing season (George et al. 2001). The moderate and concentrated grazing treatments were stocked at about 1.7 acre per animal unit month. Cooked molasses protein supplements and mineral blocks were placed along the stream banks in the pastures treated with the concentrated grazing treatments and additional animals were added to achieve the target stubble height associated with feeding and watering sites. For the concentrated grazing treatments, instantaneous stock densities equivalent to 100 cows per acre were occasionally achieved but not maintained within the corridor delineated by the cross-section transects.

Measuring stream-channel erosion. Stream-channel measurements were recorded during the first week of June at the beginning of the dry season starting with a baseline year in June 1994. Channel cross-sections were measured using methods outlined by Bauer and Burton (1993). For each stream reach, 10 permanent cross-section transects, 20 to 30 feet long, were placed perpendicular to the stream channel at a distance of 1 to 1.5 times the channel width apart (fig. 2). The transects were marked with permanent stakes and referenced to a permanent benchmark. Stream-channel elevation was determined every 6 inches (15 centimeters) along the transect using a stretched tape, laser level and stadia rod. For each transect, we measured width at bankfull, distance from the left permanent stake to both right and left bank at bankfull height, depth every 6 inches, and maximum depth. Cross-sectional area, channel average depth and width-to-depth ratio were calculated. Pasture averages for each morphological parameter were calculated from the 10 transects in each pasture. Cross-sectional area of the channel was determined using bankfull elevations following the methods of Rosgen (1996). Elevation and position readings of the permanent end-stakes were checked with benchmark elevations each year.

Measuring groundcover. Groundcover was determined using the line-point transect method (Bonham 1989) along the same transects used to survey elevations for stream-channel morphology (Bauer and Burton 1993). Bare ground was calculated by subtracting the percentage of groundcover from 100.

To separate cattle impacts on the channel bank from the adjacent floodplain and uplands, the line-point transect was divided into two sections on each side of the channel (fig. 2). The channel bank is the often-steep component of a stream channel extending from the channel bottom to the top of the bank. This section includes the point often defined as “bankfull” (Rosgen 1996). Bare ground was determined at five points along the left and right channel banks: top of bank, bottom of bank, and one-quarter, one-half and three-quarters of the distance from the top of the bank to the channel bottom (fig. 2). The stream-channel approach extended 9 feet (270 centimeters) from the top of the bank and included varying portions of the floodplain (Rosgen 1996) and uplands depending on channel morphology along the channel reach. Bare ground was determined from the top of the bank to 3 feet at 6-inch intervals,

Fall comparison of stream channel in concentrated grazing treatment, *upper,* and no grazing, *lower*.

Comparison of sediment trap in a vegetated area, *upper,* and sediment trap in an adjacent trail, *lower*.

and at 1-foot intervals from 3 to 9 feet along the stream cross-section transect.

Bare ground, channel effects

There were significant ($P < 0.001$) increases in bare ground on the channel bank and approach due to dry-season concentrated grazing when compared to the ungrazed control (fig. 3). Bare ground for the other grazing treatments was not significantly different from the ungrazed control or the dry-season concentrated treatment. These results indicate that practices causing cattle to congregate near stream channels during the dry season can significantly decrease groundcover, which protects the soil surface from erosion. Because these streams are dry during the summer they are generally not attractive to cattle. Therefore, the intensity of grazing and trampling resulting from the concentrated grazing treatment is unlikely to occur under proper stocking rates and grazing practices.

No significant ($P > 0.05$) stream-bank erosion was detected when each stream-channel measurement (width, distance to right and left bank, maximum depth, mean depth, cross-sectional area or width-to-depth ratio) for each of the five grazing treatments was averaged across all years. Stream-channel depth changed significantly ($P < 0.05$) from year to year, reflecting the seasonal and annual movement of bedload along the stream-channel bottom. The greatest between-year change was from 1996 to 1997 — an above-average rainfall year — resulting in higher-than-normal flow events that scoured bedload sediment from the channel, increasing stream-channel depth.

In their review, Trimble and Mendel (1995) found conflicting reports on the relationship between grazing along stream channels and sediment loss from stream banks. Several of these studies reported that increased channel width was the result of sloughing of undercut banks. The stream-channel banks in this study were not undercut, and could not achieve this form under any grazing scheme due to the sandy soil type and dominance of shallow-rooted annual vegetation.

We observed grazing and trampling along the stream-channel bank by cattle in the treated pastures, yet detected no change in channel width at bankfull. Fine-textured and wet stream-bank soils have been shown to be a factor in vulnerability to erosion (Clary and Webster 1990; Wolman 1959; Hooke 1979; Marlow and Pogacnik 1985; Marlow et al. 1987). The stream-bank soils in our study may be less likely to erode because they are well-drained coarse sands that have a low water-holding capacity. Trimble and Mendel (1995) suggested that watersheds subjected to high-intensity, long-duration storms generating high stream discharges were more vulnerable to stream-bank erosion than watersheds that receive relatively

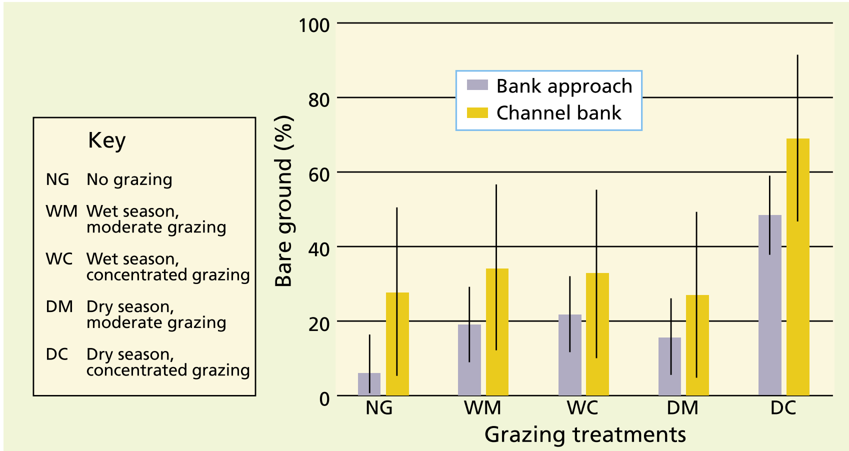


Fig. 3. Comparison of effects of fall treatment on bare ground (%) for bank approach and channel bank. Bars indicate 95% confidence level.

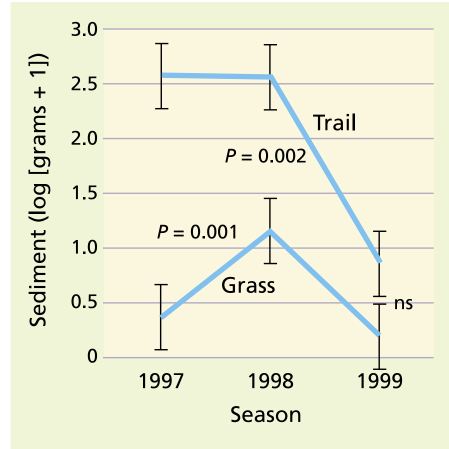


Fig. 4. Comparison of sediment from trails and adjacent grass-covered surfaces for three water years.

equitable flow from snowmelt. During our study one or more high stream discharges occurred each year, lasting for only a few hours during and following a storm. However, such single storm events were not intense or sustained enough to lead to significant erosion. Lack of high-intensity rainfall and runoff early in the rainy season may reduce stream-bank erosion. While intense grazing and trampling can leave unvegetated loose soil at the beginning of the rainy season, low-intensity rainfall, characteristic of the early rainy season, results in germination and seedling establishment that stabilizes grazed and trampled soil surfaces before periods of more intense rainfall begin.

Channel deepening was detected in the control treatments, indicating a loss of bedload sediment from the control reaches. Treatment randomization within each stream (block) resulted in the controls being placed at the lowest or next-to-lowest pasture in the sequence of five pastures along each stream. One might expect channel depth in the controls to become shallower if they were influenced by the delivery of sediment from upstream grazed treatments, but not for the channel to deepen. While there was no significant change in channel width, there was a trend toward channel narrowing that may have resulted in increased stream power, which could have eroded bedload sediment in the control pastures.

Another interpretation of the stream-channel study is that the cross-section method frequently recommended for detecting stream-channel erosion is not sensitive enough to detect the scale of erosion induced by the activity of grazing cattle. Furthermore, erosion resulting from episodic high-flow events may mask grazing-induced erosion. More refined methods of detecting erosion and longer term studies of grazed and ungrazed stream reaches may be the only means of separating grazing-induced erosion from other sources (such as natural and rodent-caused erosion, and roads).

In summary, the risk of grazing-induced stream-bank erosion in the granitic soils of the southern Sierra Nevada foothills is low because: (1) stream banks are not vertical, lowering the risk of bank undercutting and eventual sloughing; (2) the soils lack the fine texture and high water-holding capacity often associated with stream-bank erosion; (3) these southern Sierra Nevada foothills are not subject to long-duration, high-intensity storms; and (4) bare soil surfaces at the beginning of the rainy season are stabilized by newly established seedlings before periods of intense rainfall begin.

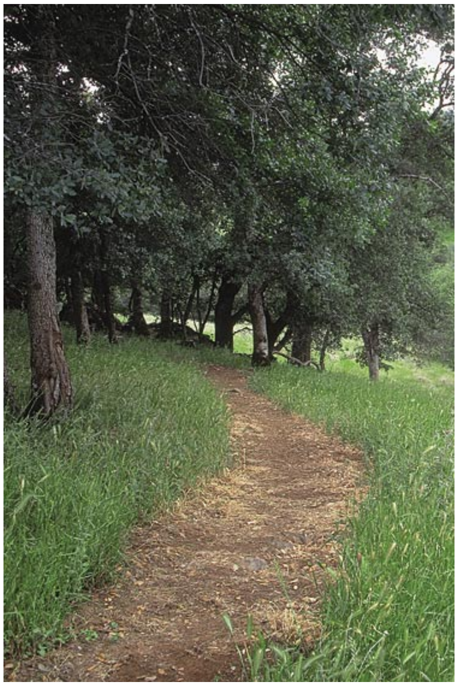
Sediment and cattle trails

During the 1997, 1998 and 1999 water years, sediment traps (Wells and Wohlgemuth 1987) were placed in pairs at several locations along stream channel 2 (fig. 1) that drains the research watershed at the San Joaquin Experimental Range. Traps were sheet-metal boxes open on one side to catch sediment. One of each pair of traps was placed in a cattle trail near the point where the trail crosses the stream channel. The second sediment trap of each pair was placed in well-vegetated areas of similar slope and slope-length adjacent to the trap in the trail. Throughout the rainy season the sediment traps were emptied as needed during and following storms. Sediment samples were dried and weighed. ANOVA was used to separate treatment and year differences.

Sediment transport was significantly greater in cattle trails than in vegetated areas in the rainfall years ending in 1997 and 1998 (fig. 4). There was no significant difference in 1999. In 1997 and 1998 there was sufficient rainfall to generate measurable runoff, and the intermittent streams began flowing in January of those two rainfall years. Rainfall in 1999 was low, resulting in little runoff and sediment movement in cattle trails. While cattle-trail crossings affect a very small total of the channel length within the watershed, the results of this study suggest that trails can be an important, management-caused conduit of sediment from the variable-source area to the stream channel. Following a major runoff event, we observed diversion of intermittent stream-channel flow into a cattle trail forming a new channel.

Cattle prefer to travel along established trails. In steep terrain, trails provide routes from water sources to preferred foraging sites. Trailing increases as the distance between foraging sites and water sources increases. In steep terrain, one trail may cross

Suzanne Paisley



Cattle trails can aid the flow of sediment into streams. By reducing the distance between foraging and watering sites, the formation of cattle trails can be reduced.

several stream channels. Several trails are common in the steep terrain of foothill rangelands, resulting in many trail crossings of each stream channel. Regular trampling by livestock keeps these trails devoid of vegetation throughout the year and reduces the infiltration rate, resulting in increased surface runoff along trails, especially along the downhill approach to stream crossings. During the dry season cattle trampling loosens surface soil, providing a ready source of sediment during the rainy season. The trails become a conduit for surface runoff and a source of sediment.

Reducing stream-channel impacts

To limit cattle impacts on stream channels, especially on public lands, mitigations such as reduced stocking rates, grazing lease termination, and fencing of streams and riparian areas have frequently been implemented. These practices can devastate the economic viability of range livestock enterprises, reducing their competitive ability and adversely affecting the economies of rural communities. Furthermore, livestock exclusion limits our ability to use grazing to manage wildlife habitat, fire fuel loads and weed infestations. Livestock grazing impacts, such as stream-channel erosion and impaired water quality, can often be addressed with management practices that alter livestock distribution on the landscape. While lease termination and fencing are certain methods of reducing livestock impacts on stream channels and water quality, less restrictive management changes such as strategic placement of water sources and supplemental feeding sites away from critical areas have been shown to reduce livestock grazing impacts (Frost et al. 1989).

Trailing is reduced when the distance between foraging sites and water sources is reduced. Adequate stock-water development can lead to improved control of cattle distribution. Strategic placement of fencing may also reduce trailing. Sediment and other livestock-generated, nonpoint source pollution sources could be substantially reduced with increased water sources on foothill ranches. These rangeland improvements should receive high priority in the allocation of agency conservation and pollution-control funding.

Researchers at UC Davis, USDA and other Western universities are currently studying the effectiveness of traditional distribution practices for attracting livestock away from environmentally critical areas or into areas to be grazed for weed control. The results of these studies will be used to fine-tune our knowledge of how livestock use Western landscapes and to improve our ability to predict the best placement of stock water and supplement sites.

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RESEARCH ARTICLE

Long-term grazing study in spring-fed wetlands reveals management tradeoffs

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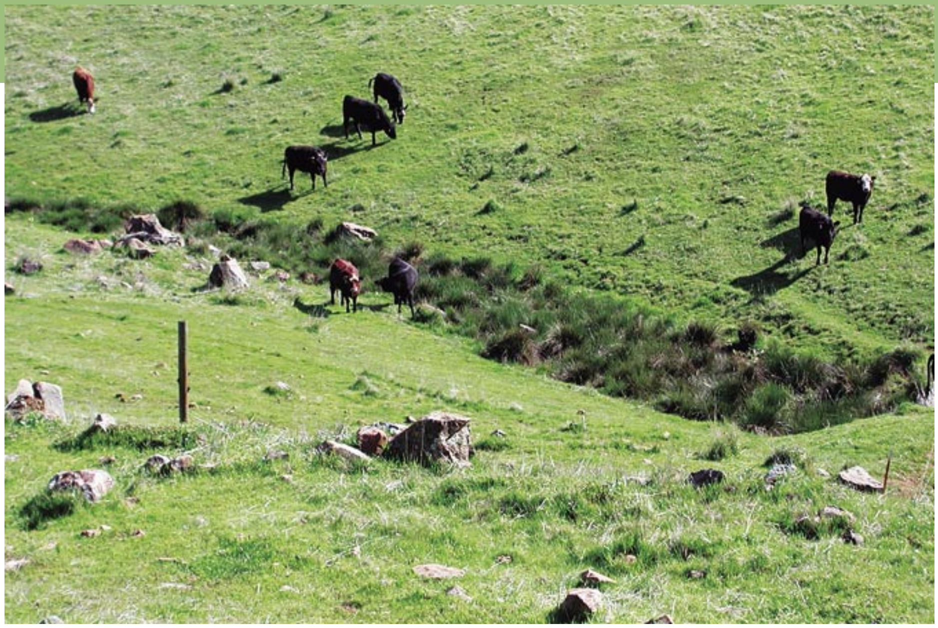


Oak-woodland springs provide green habitat and water throughout California's Mediterranean-style dry season, making them highly desirable ecosystems, islands of biodiversity and high productivity.

Spring-fed wetlands perform many important functions within oak-woodland landscapes, and livestock grazing modifies these functions. We used 10-year (long-term) and 3-year (paired-plot) experiments to better understand grazing management effects. We studied spring ecosystem responses in plant composition, diversity and cover; channel morphology; water quality; aquatic insects; and greenhouse gases. Lightly and moderately grazed wetlands exhibited lower insect family richness than ungrazed springs. Plant cover was maintained for the first 7 years of grazing, and plant diversity was not significantly affected. At the same time, removal of grazing decreased emissions of the greenhouse gas methane, and increased nitrate levels in spring waters. The results reveal important management tradeoffs relative to key response variables. In general, light cattle grazing at springs appears to be desirable from an ecosystem function perspective.

Wetland ecosystems are highly productive and valued for numerous reasons including wildlife habitat, biodiversity, water quantity and quality, and human uses. They are also relatively small ecosystems, occupying less than 1% of the state. Because livestock are thought to damage the physical, chemical and biological integrity of these systems, they are subject to government regulations, ranging from seasonal use requirements to complete livestock removal (Allen-Diaz and Jackson 2002). Livestock grazing can affect the functioning of spring-fed wetlands by acting as a nutrient filter and altering plant community composition (Jackson 2002).

These systems are also highly variable, making it difficult to predict responses to management (Allen-Diaz et al. 2001). For example, first-order (headwater) and fourth-order streams (such as the Yuba River) may have similar vegetation, but their responses to grazing may differ because of substrate (the bedrock, gravels and soils on which plants grow), slope or other environmental differences.

Spring-fed wetlands of the oak woodlands fall into two broad categories — rocky and marshy (Allen-Diaz and Jackson 2000). Where spring water emerges in and around rocky substrates, little soil development occurs. Water quickly forms channels, and overstory trees and shrubs are frequently present. The rocky wetlands typically maintain two distinct zones, an area immediately surrounding the emergent water source (referred to as springs) and the resulting channelized creek (fig. 1A).

On more shallow slopes, the flow of emergent water is slower and more diffuse, allowing the development of dense, herbaceous vegetation, which further reduces flow. These marshy sites typically do not support trees or shrubs, probably because of anaerobic soil.

Grazing and soil-water research

Rangelands occupy about 57 million acres in California. About 42% of these acres are privately owned and provide most of the forage for California's cattle industry. Approximately 9,000 miles of streams and 125,000 acres of wetlands occur on California rangelands. Many consider livestock grazing on rangeland a potential nonpoint source of pollution and thus, a serious threat to the health of California waters. Our research carefully examines these concerns.

In a long-term study, Experiment A, we tracked species composition and cover for more than a decade, primarily on rocky-type wetlands, under three levels of grazing intensity at the UC Sierra Foothill Research and Extension Center (SFREC) east of Marysville, Calif. (Allen-Diaz and Jackson 2000). Species composition was recorded in early June

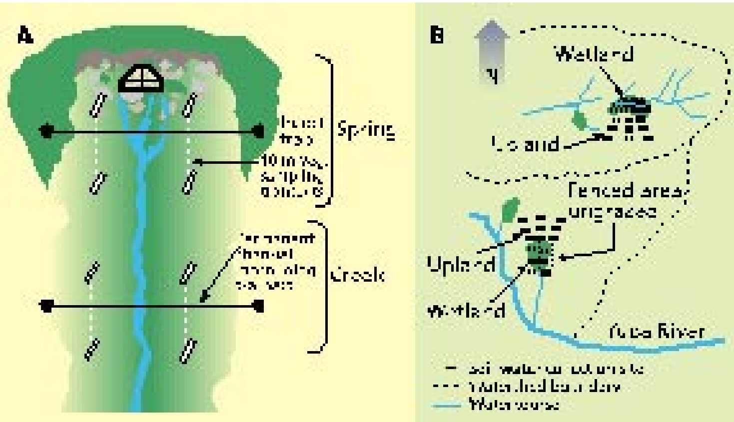


Fig. 1. Typical morphology of rocky spring-fed wetlands; Experiment (A) and (B) study layouts.

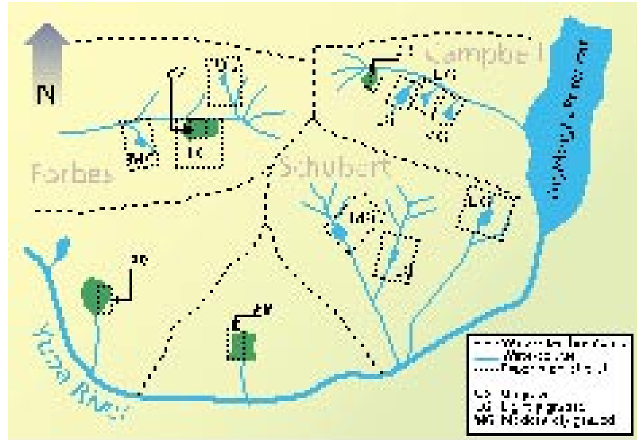


Fig. 2. Location of experimental plots at the UC Sierra Foothill Research and Extension Center. The 10-year (Experiment A) sites were in Forbes, Campbell and Schubert watersheds; the 3-year study (Experiment B) sites were Forbes Valley (FV), Poleline Ridge (PR), Campbell Roadside (CR) and Fireline Ridge (FR).

each year from permanent 16.25- or 32.5-foot (5- or 10-meter) line-point transects, which were randomly located on either side of the channel within the wetland zone. Changes in stream-channel shape (morphology)(Allen-Diaz et al. 1998) and water quality (Campbell and Allen-Diaz 1997) were also examined for approximately 5-year periods on the same sites (fig. 2). Channel morphology changes were recorded along two randomly placed 32.5-foot (10-meter) line-point transects located perpendicular to the flow of the spring or creek. We collected water samples at the springhead, or spring source, and in the creek and analyzed them in the field using a HACH DREL2000 Water Testing Kit.

In a paired-plot study at the SFREC, Experiment B, we examined marshy springs to closely evaluate soil-water nitrate levels and greenhouse-gas emissions for 3 years. We collected soil water from preinstalled, porous, soil-water cup samplers (Model 1900, SoilMoisture Equipment, Santa Barbara). When possible, samples of upland soil water and wetland surface water were collected monthly (fig. 1B). Within the wetland, surface-water samples were collected in 100-milliliter (mL) specimen cups to assess nitrate output and compare with upland soil-nitrate levels. The UC Division of Agriculture and Natural Resources Analytical Laboratory analyzed water samples by a diffusion-conductivity analyzer. Carbon (CO_2), nitrogen (N_2O) and methane (CH_4) gas emissions were collected monthly from March to September 2002 (with the exception of May) in vented static flow chambers. Gas samples were analyzed by gas chromatography (SRI Instruments, Torrance, Calif.).

All sites had historically similar fall-winter-spring grazing histories that left approximately 600 to 750 pounds per acre residual dry matter (RDM), or aboveground biomass, in the uplands. In 1993, sites within watersheds were randomly assigned to the following treatments in a randomized block design:

- Grazing removal (ungrazed, UG, approximately 1,200 to 1,500 pounds per acre upland RDM).
- Light grazing (LG, approximately 800 to 1,000 pounds per acre upland RDM).
- Moderate grazing (MG, approximately 600 to 700 pounds per acre upland RDM).

Experiment B took place on the marshy sites, to take advantage of their greater area. Marshy springs were sampled in 1999 and 2000. Then, these sites were divided so that grazing treatment comparisons could be made within sites (Jackson 2002). This meant that only two treatment levels could be compared — moderate grazing and grazing removal. Posttreatment samples were collected in 2001 (fig. 2).

Grazing effects on wetlands

Plant species composition. Changes in species composition provided evidence of fundamentally different vegetation dynamics in these systems. One way to examine these changes is with a CCA (Canonical Correspondence Analysis) site score, an index variable that collapses species composition into one measure. This statistical technique is useful for interpreting plant community structure that is related to environmental variables (McCune and Grace 2002). For example, in this case we used it to compare changes in species composition related to grazing levels in Experiment A. The CCA site scores were much more variable from year to year for springs than for creeks on the rocky-type wetlands (fig. 3). Implications for management are that species composition can be manipulated by altering the grazing intensity along creeks. In springs, how-

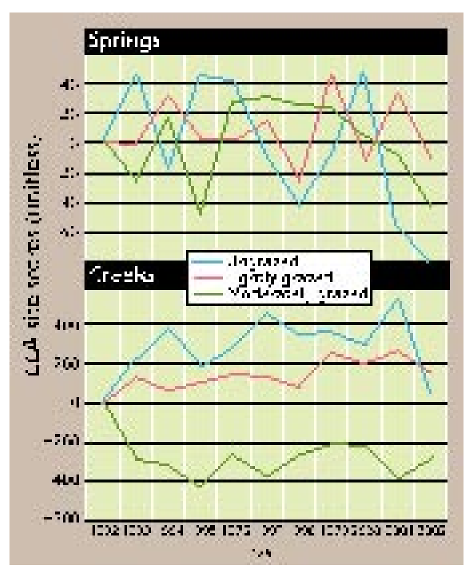


Fig. 3.* Species composition over time as affected by grazing intensity in Experiment A.

*Note: Figures 3 and 5 in this on-line/PDF are corrected from the printed version.

Cattle grazing causes visual changes in oak-woodland spring structure. However, spring composition is stable over time, and hoof-caused hummocks do not result in detrimental changes to composition, productivity or water quality.

ever, species composition is controlled by the vagaries of climate, not by grazing intensities at the levels we studied.

Herbaceous diversity. No significant differences in the total number of species (relative to pretreatment 1992 values) were observed at any of the wetland sites. Common species are listed in table 1. In both experiments, there were no changes in the relative amounts of native and nonnative species over time under any grazing treatment. Lightly grazed wetlands maintained greater species evenness (maximum when all species have the same number of individuals) and diversity (Shannon-Weaver and Simpson indices) relative to 1992 pretreatment values than either ungrazed or moderately grazed plots (Jackson 2002). At creeks, moderately grazed plots maintained greater relative total species, evenness and diversity than lightly grazed and ungrazed plots, which were not significantly different from each other.

On marshy springs (Experiment B), we observed decreased diversity with grazing removal for 1 year. Our results indicate that light grazing on spring-fed wetlands and moderate grazing on resultant down-slope creeks maintain current plant diversity.

Herbaceous cover. Because plant cover conserves soil, improves water quality and is correlated with plant productivity, it is an important measure of ecosystem health. After 7 years, we found no significant differences in herbaceous cover among grazing intensity treatments. However, by 2002, moderate grazing resulted in a significant decrease in plant cover. Sustained grazing at moderate or higher intensities on these systems is not desirable from an ecosystem conservation perspective, to prevent significant erosion and prevent undesirable changes in species composition. However, our short-term study showed that occasional moderate grazing does not significantly affect plant cover.

Channel morphology. Five years of data from permanent cross-section transects of the springs and resultant creeks in Experiment A showed no changes in channel morphology due to grazing treatment (Allen-Diaz et al. 1998). Ungrazed springs and creeks exhibited more year-to-year variability than grazed springs and creeks, although these differences were not statistically significant. Channel widening and flattening of waterways can have important effects on fish populations, especially in second and lower-order streams.

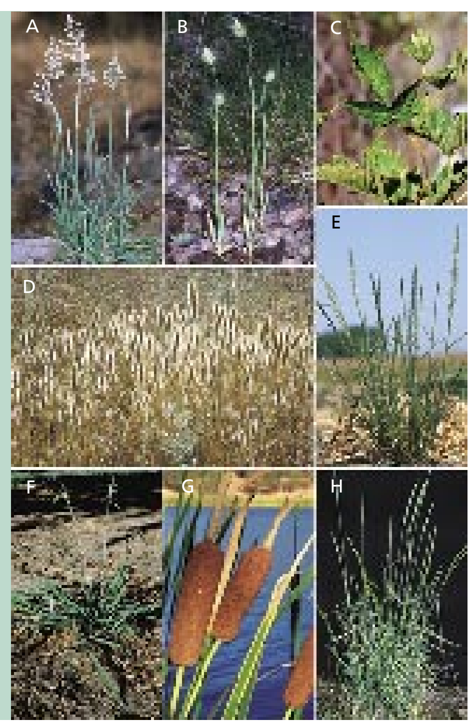
Water quality. Over a 5-year period we monitored nitrate, orthophosphate, dissolved oxygen, temperature and pH in surface water emerging from rocky spring-fed systems. We found no

TABLE 1. Dominant herbaceous-layer plant species in springs and creeks at Sierra Foothill Research and Extension Center, Experiments A and B

Common name	Species	Family	Native/ introduced*
Blue wild-rye **(H)**	*Elymus glaucus*	Poaceae	N
California blackberry **(C)**	*Rubus ursinus*	Rosaceae	N
California grape	*Vitis californica*	Vitaceae	N
Common spike-rush	*Eleocharis macrostachya*	Cyperaceae	N
Dallis grass **(F)**	*Paspalum dilatatum*	Poaceae	I
Dogtail **(B)**	*Cynosurus echinatus*	Poaceae	I
False brome	*Brachypodium distachyon*	Poaceae	I
Flat sedge	*Cyperus odoratus*	Cyperaceae	N
Hedge nettle	*Stachys albens*	Lamiaceae	N
Italian ryegrass **(E)**	*Lolium multiflorum*	Poaceae	I
Italian thistle	*Carduus pycnocephalus*	Asteraceae	I
Narrow-leaved cattail **(G)**	*Typha angustifolia*	Typhaceae	N
Rabbitfoot grass **(D)**	*Polypogon monspeliensis*	Poaceae	I
Rattlesnake grass	Briza minor	Poaceae	I
Ripgut brome	*Bromus diandrus*	Poaceae	I
Seashore vervain	*Verbena litoralis*	Verbenaceae	I
Soft chess	*Bromus hordeaceus*	Poaceae	I
Velvet grass **(A)**	*Holcus lanatus*	Poaceae	I
Water cress	*Rorippa nasturtium-aquaticum*	Brassicaceae	N

* N = native, I = introduced (Hickman 1993).

Photo credits: Joseph M. DiTomaso (A–E), Jack Kelly Clark (F), ANR Communication Services (G), Suzanne Paisley (H).



Removal of livestock grazing resulted in increased levels of nitrate in wetland waters and thus higher levels of nitrate pollution compared to grazed springs.

significant differences among grazing intensity treatments in Experiment A (Campbell and Allen-Diaz 1997).

In Experiment B, marshy spring-fed wetlands appeared to intercept and retain nitrate as it moved along its hydrologic path from upland soils to emergent spring waters (Jackson and Allen-Diaz 2002). Furthermore, the removal of livestock grazing from these wetlands impaired the ability of the springs to retain nitrate. Grazing removal allowed dead plant material to accumulate (fig. 4), thereby inhibiting plant production (hence, plant nitrogen demand), resulting in stream-water nitrate concentrations that far exceeded the U.S. Environmental Protection Agency's surface-water maximum standard of 714 μmol[5] (micromoles[5] or 10 parts per million [ppm])(fig. 5).

Aquatic insects. Aquatic insects are frequently used to evaluate the ecological integrity of streams. Reduced community numbers may indicate organic pollution or habitat degradation. Insects were identified to the family level from a 1-year sample (collected quarterly) in Experiment A. Analysis was limited to families with aquatic genera; wholly terrestrial families were excluded. Lightly grazed and moderately grazed wetlands exhibited lower family richness than ungrazed springs at each sampling date. The lowest cumulative family-richness values (sum of all families for the year) were found for moderately grazed springs followed by lightly grazed springs.

Greenhouse gases. Methane (CH_4) is a greenhouse gas that is important to global climate change. It is "radiatively active," warming the lower atmosphere by absorbing thermal radiation. Methane contributes approximately 20% of terrestrial trace gases into the atmosphere (Bouwman 1990; Cicerone and Oremland 1988). The atmospheric concentration of methane has increased from 0.7 to 1.7 ppmv (parts per million by volume) in the last 200 years (Tyler 1991). When compared to carbon dioxide (CO_2), the relative contribution of methane to the Earth's energy balance exceeds its relative concentration in the biosphere. This is because methane generally absorbs reflected radiation 25 times more effectively than carbon dioxide (Bartlett and Harriss 1993).

Wetland systems are generally considered sources of methane because biomass rots in anaerobic conditions (Schlesinger 1997). We assessed the effects of grazing on methane fluxes (the amount released into the air) in spring-fed wetlands in Experiment B (Oates 2002). Air temperature had the strongest influence on methane flux, followed by soil water content and grazing presence or absence. The mean methane flux was 9.29 ± 4.37 mg CH_4–C/m^{-2}/hr^{-1} (mean ± S.E.) with a range of –0.19 to 147.88 mg CH_4–C/m^{-2}/hr^{-1} (methane flux measured as carbon in the form methane in milligrams per square meter per hour). Water content at these sites was 39.66% ± 2.29%, with a range of 14.51% to 60.64%. Grazing removal significantly decreased methane emissions; grazed was 16.01 ± 8.48 mg CH_4–C/m^{-2}/hr^{-1}, and ungrazed was 2.57 ± 1.15 mg CH_4–C/m^{-2}/hr^{-1}.

Guidelines and research gaps

Spring-fed wetlands are small, patchy ecosystems nestled within a matrix of oaks and annual species; they are important in overall landscape structure and function in a way that is disproportionate to their size. Much of the water exiting California oak-woodland watersheds passes through these highly productive spring-riparian zones, which are located at the interface of the terrestrial-aquatic ecosystem. Our data indicates that wetland vegetation in these zones, typically cattails *(Typha angustifolia)*, sedges, rushes and perennial grasses, act as nutrient filters for waters emerging at the soil surface.

High herbaceous plant production is one of the key factors for maintaining ecosystem services, by promoting carbon sequestration and nutrient conservation from the terrestrial landscape. A factor such as grazing, which influences ecosystem productivity, is an important control on ecosystem services.

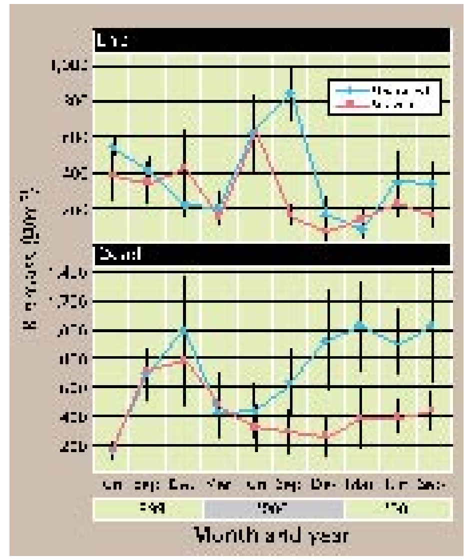


Fig. 4. Live and dead plant biomass from grazed and ungrazed plots in Experiment B.

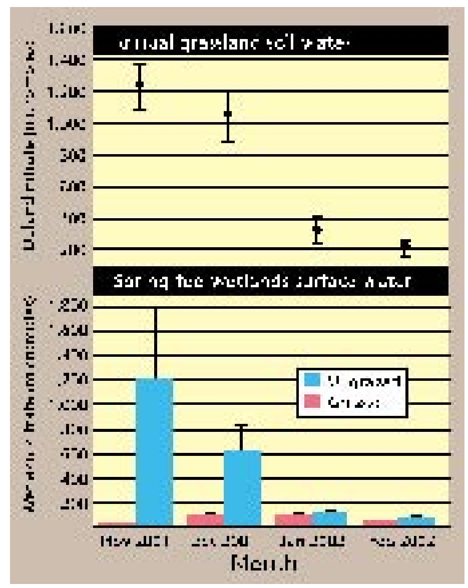


Fig. 5.* Soil and surface-water nitrate concentrations from Experiment B during winter 2001-2002.

Livestock grazing also shapes plant communities in these systems. Our studies show that nutrients (nitrogen) from the surrounding environment flow into the spring systems, supporting great productivity in concert with water and energy surpluses. Removal of livestock grazing resulted in increased levels of nitrate in wetland waters and thus higher levels of nitrate pollution compared to grazed springs. When grazing was removed, these

***Note: Figures 3 and 5 in this on-line/PDF are corrected from the printed version.**

Jack Kelly Clark

Research on the ecological impacts of cattle grazing was conducted over a 10-year period at the UC Sierra Foothill Research and Extension Center in Browns Valley (near Marysville).

Spring-wetland ecosystems evolved with grazing wildlife, and later domestic animals. Light livestock grazing fosters plant diversity and helps to maintain nitrate levels in spring waters.

systems underwent greater changes in plant composition resulting in decreased plant diversity. Some degree of herbivory appears desirable from an ecosystem function perspective, although consistently high grazing intensities will reduce herbaceous cover to undesirable levels.

Future work should examine ecosystem interactions with the atmosphere as greenhouse-gas concentrations continue to rise. The removal of livestock grazing from these systems, especially during the early summer when the combination of temperature and soil water is at an optimal level for methane production, may reduce methane emissions. However, nitrate levels in spring waters increase with grazing removal, and preliminary data shows that grazing removal also increases the production of the greenhouse gas nitrous oxide (N_2O).

In addition to introduced cattle, spring-wetland systems are grazed by wildlife of all kinds. Grazing is an integral part of these systems; it evolved with them, and the plants and wildlife grazers (and later domestic grazers) are adapted and continue to adapt to each other. These studies demonstrate the importance of and need for long-term research, and show that tradeoffs exist for different management scenarios and different measured environmental factors.

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Transparency tube provides reliable water-quality measurements

Randy Dahlgren
Erwin Van Nieuwenhuyse
Gary Litton

We examined the efficacy of using transparency-tube measurements to estimate turbidity, total suspended solids (TSS) and particulate nitrogen and phosphorus concentrations in several California waterways. Just as lowering a black-and-white disk (Secchi disk) into a lake provides a convenient way to measure its water clarity, a transparency tube offers a practical alternative for measuring water clarity and suspended solids concentrations in California streams and waterways. While transparency relationships with turbidity and TSS are strongest within a given sampling location, these relationships are relatively robust across a wide range of water bodies displaying contrasting conditions. However, transparency-tube measurements appear to have limited value in predicting particulate nutrient concentrations, even at a given sampling site. The low cost, ease of use and excellent repeatability of measurement make the transparency tube a potentially valuable tool for anyone interested in monitoring water quality, including farmers, ranchers, citizen volunteer groups, schools and local governments seeking to get involved in watershed monitoring programs.

Water clarity — a measure of suspended solids — is an important indicator of the basic health of a stream or river. The upper Mokelumne River, *left*, is clear, while Orestimba Creek in the San Joaquin Valley is clouded by sediments from irrigation return flows. The authors studied input waters similar to these.

Suspended solids are a common source of water impairment in streams. The Clean Water Act section 303(d) list for total maximum daily load (TMDL) development in California identified 152 water bodies and river segments as impaired by sediment-related problems in 2002 (SWRCB 2003). These water bodies include 165,000 acres of bays and harbors, 4,513 acres of estuaries, 94,253 acres of lakes and reservoirs and 16,953 miles of rivers and streams. Although suspended solids occur naturally in stream waters, human activities can greatly increase their concentrations. Several types of materials contribute to suspended solids, including soil particles, aquatic organisms (such as phytoplankton and zooplankton) and small fragments of dead plants. Sources of suspended solids in streams include waste discharge, urban runoff, eroding stream banks, excessive algal growth and soil erosion from construction, forestry or agricultural sites. Suspended sediments have numerous effects on water quality that impact the health and integrity of aquatic ecosystems (Cordone and Kelly 1961; Kirk 1994; Lloyd et al. 1987).

Monitoring of suspended solids has become an essential part of programs to reduce nonpoint source pollution, such as those imposed by the Clean Water Act through the TMDL process. Nonpoint source pollution originates from diffuse and hard-to-identify sources, such as runoff from urban areas, agriculture and forestry. Regular monitoring of suspended solids, like checking your blood pressure on a regular basis, provides a measure of the general health of a water body. This data can be used to identify water bodies impaired by suspended solids, prioritize areas for additional monitoring and research, detect trends of increasing or decreasing erosion in a watershed, and document the effectiveness of stream-restoration projects.

Three commonly used methods to evaluate stream-water suspended solids concentrations are total suspended solids (TSS), turbidity and transparency (Secchi disk and transparency tubes). TSS measurements (milligrams per liter [mg/L]) involve quantifying the mass (mg) of solids retained on a 0.45 micron (μm) filter following filtration of a known quantity (L) of stream water. This laboratory method is time-consuming and requires a high-

Regular monitoring of suspended solids, like checking your blood pressure on a regular basis, provides a measure of the general health of a water body.

precision analytical balance. Turbidity is a measure of light-scattering by suspended particles and provides a measure of cloudiness (or alternatively, clarity). Turbidity is measured with a nephelometer (turbidimeter, $900 to $2000) in units called nephelometric turbidity units, or NTUs. The method can be performed in the field and is highly accurate and rapid (about 1 minute). A general rule of thumb is that 1 mg TSS/L is approximately equal to 1 to 2 NTUs of turbidity.

The transparency tube (turbidity tube) is a clear plastic tube marked with a centimeter scale and a white-black pattern (Secchi pattern) painted on the bottom. Typical tubes range in length from 24 to 48 inches (60 to 120 centimeters), with an inside diameter of 1.8 inches (4.5 centimeters) and outside diameter of 2 inches (5.0 centimeters), and a water release valve at the bottom to drain the tube. Stream water is poured into the tube until the white-black pattern disappears. Water is then released from the bottom valve until the pattern becomes visible. The depth (centimeters) of water is read from the scale attached to the tube. It is important to shade the tube with your body by facing away from the sun and to perform the measurement without sunglasses.

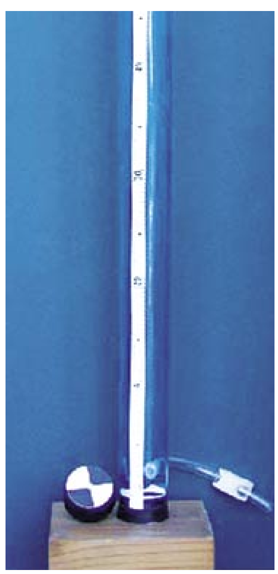
Transparency tubes have an advantage in stream waters that are too shallow or too swift for the traditional Secchi disk measurements. Water samples can be collected safely using a bucket and rope thrown from a bridge or near shore. Similar to other water-clarity measurements, transparency measurements can be rendered inaccurate in some cases by highly colored waters (due to dissolved organic matter). Transparency readings using tubes from different sources may give slightly different readings, so care must be taken in comparing data from different sources. Transparency tubes can be purchased from scientific supply houses ($35 to $60) or they can be homemade at low cost.

This research tested the hypothesis that transparency-tube measurements may be used as a simple and inexpensive indicator of water-quality parameters related to suspended solids, such as turbidity, TSS concentration, and total particulate nitrogen and phosphorus concentrations. Water samples from three separate studies (15 Central Valley rivers, Stockton Ship Channel and Bay-Delta waterways) were utilized.

Importance of suspended solids

Suspended solids affect physical (such as temperature), chemical (such as nutrients) and biological (such as habitat and photosynthesis) properties of aquatic ecosystems (Cordone and Kelly 1961; Kirk 1994; Lloyd et al. 1987). The most obvious negative impact of suspended solids is their impairment of recreational use and aesthetic enjoyment of water bodies. For most people, clear water means clean water. In addition to making water cloudy, suspended solids serve as carriers of nutrients (such as phosphorus and nitrogen), trace metals (such as mercury, lead, cadmium, copper and zinc), toxins (such as pesticides, dioxins and PCBs [polychlorinated biphenyls]) and disease-causing microorganisms (such as *E. coli* and giardia). The particles may provide a mechanism for the accumulation of toxicants into the food web via ingestion. High turbidity increases the cost of purifying drinking water because particulate material must be virtually eliminated for effective disinfection. The accumulation of sediments in navigable waterways requires expensive dredging to maintain adequate channel depths.

Excessive concentrations of suspended solids have several effects on aquatic organisms. Fish gills can be clogged, which hinders gas exchange, destroys protective mucous coverings on eyes and scales, and makes fish more susceptible to infection and disease. Filter-feeding systems can be fouled, hindering the ability of aquatic predators to pursue their prey. Suspended solids may settle to the stream bottom, where they bury and suffocate fish eggs and newly hatched larvae. Fine suspended solids may cover coarser sediments and spaces between rocks and cobbles, which provide habitat for aquatic life (such as spawning gravels), especially benthic organisms (those living in or on bottom substrates in aquatic ecosystems). As a result, aquatic diversity may be greatly altered from natural conditions. To protect fish production



Typical transparency tube used to make water-clarity measurements. Water is released from the outlet valve until the black-white target at the bottom of the tube becomes visible.

UC Davis graduate student John Maynard (left) and UC Cooperative Extension specialist Toby O'Geen examine the effects of wetland treatment for water-quality improvement of irrigation tailwaters in western Stanislaus County. As shown by the transparency tube, suspended solids are effectively removed by treatment in flow-through wetlands. The transparency tube provided accurate measurements of water transparency, and is a low-cost tool that is easy to use in the field.

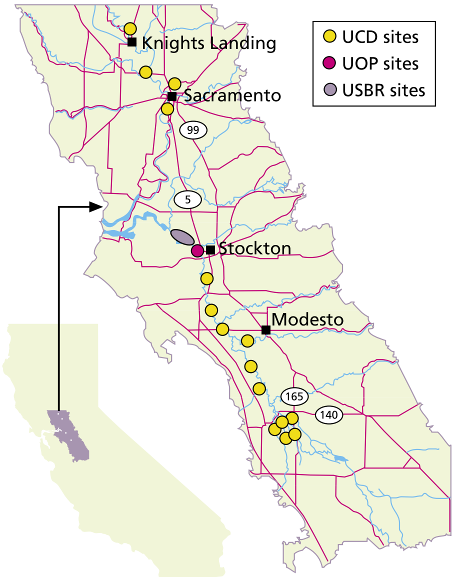


Fig. 1. Transparency-tube sampling sites. UCD includes 248 samples from 15 Central Valley rivers in the San Joaquin and Sacramento river watersheds; UOP includes 194 samples from the Stockton Ship Channel; and USBR includes 26 samples from Bay-Delta waterways.

California waterways are subject to federal total maximum daily load (TMDL) requirements for pollutants such as nutrients, pesticides and suspended solids. Wetland treatment, shown above, can improve the water quality of irrigation tailwaters before they enter the San Joaquin River. These wetlands also provide valuable wildlife habitat, groundwater recharge and temporary water storage to lessen flooding.

and other beneficial uses, California's Regional Water Quality Control Plans limit controllable increases in turbidity to levels that vary with natural background turbidity. For example, in very clear water bodies (0 to 5 NTUs), turbidity increases must not exceed 1 NTU, whereas in highly turbid systems (> 100 NTUs), increases of up to 10% are allowed.

High levels of suspended solids can also contribute to low dissolved-oxygen levels in rivers and estuaries by virtue of their effects on the production of single-celled plants called algae. In the San Joaquin River, for example, nutrients attached to suspended solids — carried by agricultural and wetland drainage — fuel extremely high levels of algae production. Bacteria decompose dead algae along with other forms of organic matter carried by the river (such as dissolved organic matter, fragmented plant materials and animal wastes) and treated sewage from cities and towns, resulting in the consumption of oxygen. Turbidity may also affect the biological oxygen demand in the San Joaquin River system indirectly through its influence on the type of algae that can grow. In low-turbidity streams, light can penetrate to the streambed, making it possible for benthic algae to predominate. Benthic algae grow in place, rather than suspended in the water, so they are not transported during the summer-fall low-flow period of high water temperature, but instead during the winter high-flow period. By contrast, in turbid systems like the San Joaquin River, a much greater percentage of the streambed material is too dark to support benthic algal production, so algae grow mostly in suspension. Suspended algae (phytoplankton) flowing with the current is transported to the lower San Joaquin River during the summer and fall months. When the phytoplankton reach the much deeper water of the Stockton Ship Channel, many die and are decomposed by bacteria, contributing to low dissolved-oxygen levels. Under these circumstances, dissolved oxygen can drop to levels low enough to delay the migration of salmon to their spawning grounds upstream.

Water samples compared

Water samples were collected from 15 Central Valley rivers (UCD: 248 samples from 10 sites in San Joaquin watershed and five sites in the Sacramento watershed); the Stockton Ship Channel (UOP: 194 samples); and Bay-Delta waterways (USBR: 26 samples) by three independent research teams (fig. 1). All samples were analyzed for transparency (1.8 inches [4.5-centimeter] inside diameter tube), turbidity and TSS, except that TSS was not determined for the Bay-Delta waterway samples. Only samples with transparency values less than 48 inches (120 centimeters) were utilized in this comparison study. In addition, Secchi disk measurements (12-inch [30-centimeter] diameter) were made at the Stockton Ship Channel and Bay-Delta waterway sites, and particulate nitrogen and phosphorus concentrations were determined for the Central Valley river samples. Particulate nutrient concentrations were calculated as the difference between total (unfiltered) and dissolved (that passed through a 0.45-micron filter) nitrogen and phosphorus. Following persulfate-digestion, nitrogen was measured conductimetrically and phosphorus was measured with the ammonium molybdate colorimetric method. All statistical analyses were performed using SYSTAT for Windows, Version 9 (SYSTAT, Evanston, Ill.).

Transparency and other parameters

Method efficacy. First, we examined the relationship of transparency to turbidity and TSS at one site to demonstrate the efficacy of the methodology across a range of hydrologic conditions. Over the course of a water year (Octo-

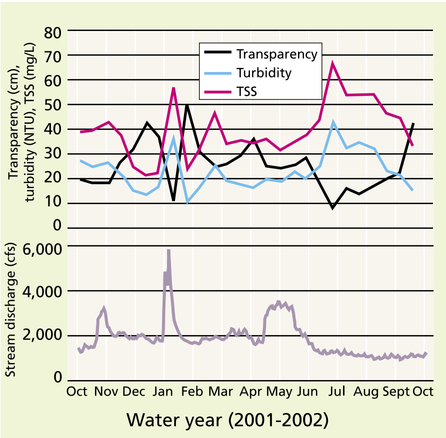


Fig. 2. Comparison of transparency, turbidity and total suspended solids (TSS) measurements over the course of a water year for the San Joaquin River at Vernalis. Transparency is inversely related to turbidity and TSS.

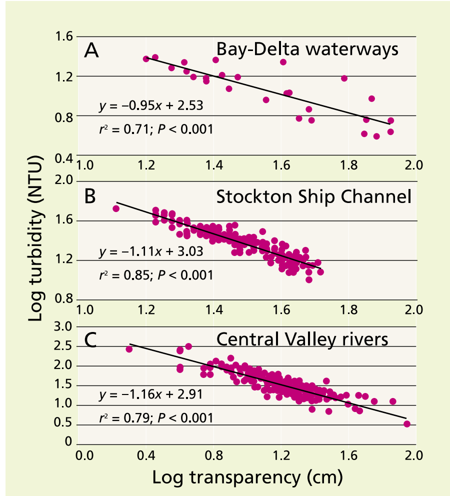


Fig. 3. Relationship between log-transformed values of turbidity and transparency for multiple sites in (A) Bay-Delta waterways, (B) Stockton Ship Channel and (C) Central Valley rivers. The tighter the clustering, the stronger the negative relationship is, showing lower transparency as turbidity increases.

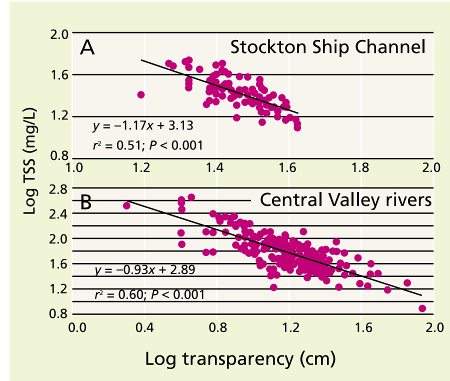


Fig. 4. Relationship between log-transformed values of total suspended solids (TSS) and transparency for the (A) Stockton Ship Channel and (B) Central Valley rivers. The tighter the clustering, the stronger the negative relationship is, showing lower transparency as TSS increases.

ber to September, to coincide with the rainy season), the measures of stream clarity in the San Joaquin River at Vernalis varied by a factor of two to three times (fig. 2). Maximum turbidity values tend to occur during winter storm events (January) and during summer low flows when irrigation return flows contribute an appreciable sediment load to the San Joaquin River. There is a strong linear relationship between turbidity and TSS ($r^2 = 0.88$), with an average value of 1.7 mg TSS per NTU. Transparency was inversely related to turbidity ($r^2 = 0.92$) and TSS ($r^2 = 0.78$), showing an exponential decay relationship that can be transformed to a linear relationship using a log-log transformation (data not shown). The stronger relationship between transparency and turbidity compared to TSS is expected because both transparency and turbidity are visual measures and are a function of light-scattering. Their relationship with TSS depends on the particle-size distribution and on the shape, color and composition of the particulate matter.

Measurement precision. The precision of measurements was examined under laboratory conditions through repeated measurements ($n = 5$) by the same individual, as well as repeated measures by different individuals ($n = 4$). The coefficient of variation (standard deviation/mean) was similar between the individual's repeated measures (3% to 4%) and the variability between individuals (4% to 5%). We found that variability among first-time users of transparency tubes under field conditions can be substantially higher. Measurements under full sunlight tend to show greater transparency compared to cloudy or low-light conditions. The presence of coarse particles (such as sand grains) may also affect readings by preferentially settling to the bottom of the tube where they cover the black-white pattern. Transparency tubes from different manufacturers may also give slightly different readings due to differences in design. Care must be taken in comparing data from different sources. Due to the number of factors that may influence transparency readings, we chose to analyze the three data sets independently rather than combining them for analysis.

Varying conditions. Next, having demonstrated that transparency-tube measurements can be made precisely and that they show a strong relationship to turbidity and TSS at a single research site, we expanded the analysis to test the robustness of these relationships across a wider range of conditions. Transparency-turbidity relationships showed a strong correlation ($r^2 = 0.71$ to 0.85) with similar slopes (−1.16 to − 0.95) and intercepts (2.53 to 3.03) across a wide range of water samples (fig. 3). This strong relationship is even more remarkable when considering that the Central Valley river samples represent 15 different streams having a wide range in the composition of suspended solids.

The relationship between TSS and transparency is not as strong as for transparency-turbidity; however, the relationship does provide substantial predictive ability ($r^2 = 0.51$ to 0.60) (fig. 4). Again, the slopes and intercepts between these two data sets are remarkably similar in spite of large differences within and between sampling sites. In contrast, the relationship between TSS and turbidity ($r^2 = 0.83$ to 0.84) (data not shown) is appreciably stronger than TSS versus transparency. We conclude that transparency is a robust measure of both turbidity and TSS; however, it is a stronger predictor of turbidity than TSS across our sampling sites.

Comparison to Secchi disk. Because Secchi disk measurements have a long tradition in hydrology and aquatic biology, the relationship between Secchi disk and transparency-tube measurements of water clarity was compared for sites in the Stockton Ship Channel and Bay-Delta waterways (Davies-Colley and Smith 2001; Preisendorfer 1986). There was a strong linear relationship ($r^2 = 0.71$) between the two measures of water clarity, with Secchi disk transparency values consistently higher (fig. 5). The relationship has a

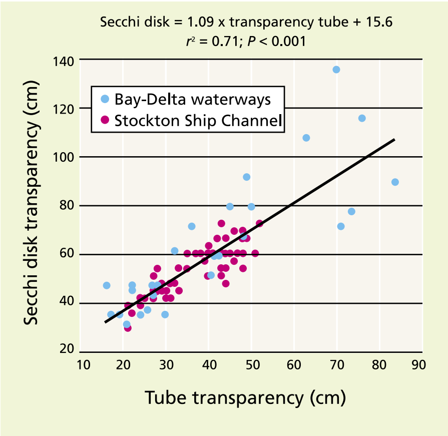


Fig. 5. Relationship between Secchi disk and transparency-tube measurements of water-column transparency for the Stockton Ship Channel and Bay-Delta waterways. Although both techniques involve visual detection of a black-and-white disk, the methods are not directly comparable.

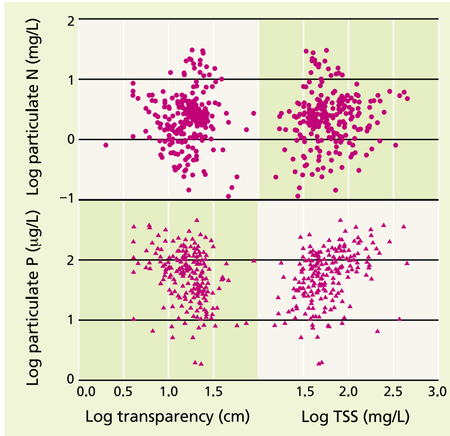


Fig. 6. Relationship between log-transformed concentrations of particulate (> 0.45 micron) nitrogen and phosphorus and transparency measurements at multiple sites in Central Valley rivers. The lack of a relationship indicates that transparency measurements cannot be reliably used to predict particulate nutrient concentrations across multiple sites.

slope near unity (1.09) with an intercept of 15.6. The offset indicated by the intercept suggests that there is a fixed systematic difference between the two methods resulting from factors such as different properties of the disk (such as diameter and pattern) and surrounding light field (such as light attenuation from transparency-tube walls). This evaluation clearly demonstrates that while Secchi disk and transparency-tube measurements are strongly related, they are not directly comparable.

Nutrient concentrations. Finally, an additional interest was to determine whether transparency-tube measurements could be used to estimate nitrogen and phosphorus concentrations contained in the particulate (> 0.45 micron) fraction. Relationships between transparency and total particulate nitrogen (P = 0.61) and phosphorus (P = 0.07) were not significant (P > 0.05) when combining data from all 15 sites (fig. 6). When examining data by site, several significant relationships were found; however, r^2 values typically ranged from 0.1 to 0.5 (data not shown). Even the relationship between particulate-matter nitrogen and phosphorus and TSS was not significant, indicating that there are between-site and temporal variations in the nitrogen and phosphorus contents of the particulate fraction (fig. 6). As such, transparency measurements had limited value in predicting nutrient concentrations of particulate matter in our study. Stronger relationships between particulate nutrient concentrations and Secchi disk measurements have been noted in waters where algae biomass is the primary source of both particulate nutrients and light attenuation in the water column (Carlson 1977; Rast and Lee 1978).

Putting transparency tubes to work

This study demonstrates that transparency-tube measurements provide a reliable method for estimating turbidity and TSS in a wide range of California water bodies. While transparency relationships with turbidity and TSS are strongest within a given sampling location, these relationships are relatively robust across a wide range of water bodies displaying contrasting conditions. Transparency-tube measurements appear to have limited value in predicting particulate nutrient concentrations, even at a given sampling site.

The low cost, ease of use, excellent repeatability and rapidity of measurement make the transparency-tube method readily available to farmers, ranchers, schools, citizen monitoring groups and local government agencies. Transparency tubes may be applied to a wide variety of monitoring activities, such as determining the spatial patterns of pollution sources within a given watershed, tracking long-term changes in water quality, examining temporal patterns in water quality (such as seasonal and storm events) and evaluating watershed-restoration activities (such as above and below a wetland, streambank restoration or construction site). For any of these monitoring activities, we recommend calibrating transparency measurements with other water-quality parameters to document the strength of these predictive relationships. Widespread use of such monitoring tools provides an excellent opportunity for citizens to play an active role in enhancing water quality in California.

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RESEARCH ARTICLE

Aerial application of clopyralid demonstrates little drift potential and low toxicity to toads

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To control yellow starthistle, a helicopter applies clopyralid (Transline). This herbicide has a broad timing window and very low toxicity, with no grazing restrictions.

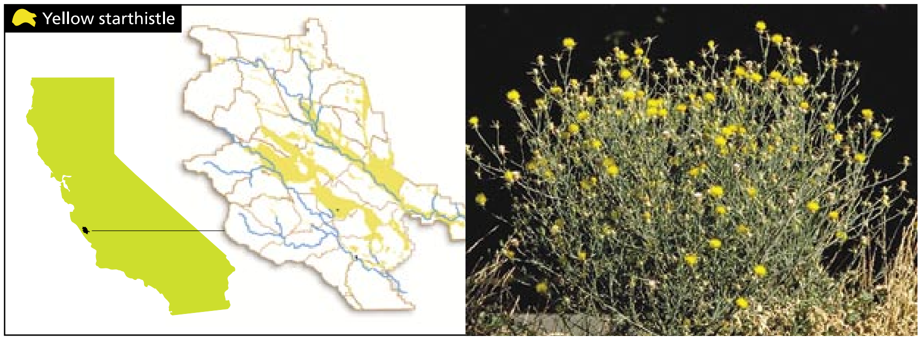
The herbicide clopyralid (Transline) is commonly applied by air to control yellow starthistle, a noxious weed, in California. In laboratory studies, clopyralid toxicity in Fowler's toad was low, indicating a wide safety margin when used under field conditions. In addition, monitoring of clopyralid drift following aerial application demonstrated that 98-foot (30-meter) buffers between treatment areas and water sources provided adequate drift protection for an adjacent stream and vernal pools. Nevertheless, to ensure that movement of the herbicide to water sources is minimized, it is important to prevent application error, particularly accidental encroachment into established buffer zones. This study demonstrated that drift potential for clopyralid was minimal even with an aerial application and a slight downwind breeze toward sensitive aquatic sites. It is also the first report demonstrating a high tolerance to clopyralid in larval toads.

Yellow starthistle is an annual, Eurasian weed commonly found along many of California's open roadsides, rangeland, wildlands, pastures and disturbed places (Maddox 1981). Since 1960, yellow starthistle has spread rapidly and currently infests an estimated 12 million to 20 million acres in California (DiTomaso, Kyser et al. 1999). Throughout the state, yellow starthistle *(Centaurea solstitialis)* decreases rangeland utilization, lowers forage quality and production, hinders military and recreational land use, and displaces native plant and animal habitats.

Several management methods can be used to control yellow starthistle including tillage, mowing, grazing, biological control, herbicides and revegetation with competitive perennial species (DiTomaso, Lanini et al. 1999; DiTomaso et al. 2000; Thomsen et al. 1996). With the 1998 registration of clopyralid (Transline) for wildland use in California, aerial application has become a common, effective control method for yellow starthistle. Clopyralid is a picolinic acid herbicide that mimics the activity of naturally occurring auxins in plants; it is used at low rates and is selective for the control of some broadleaf species, particularly members of the sunflower and pea families. In addition, clopyralid has a broad timing window, does not appear to negatively impact insect biological-control agents (Pitcairn and DiTomaso 2000) and has a very low toxicity (signal word: "caution") with no grazing restrictions.

Fort Hunter Liggett (FHL) is a 260-square-mile military installation located in southern Monterey County, on the eastern side of the Santa Lucia Mountains. The property is largely wildland and contains a number of habitats, including chaparral, woodland, grassland, vernal pools and marshes. A remarkable number of animal and plant species, several of them rare, are present. A state-listed species of concern, the California tiger salamander *(Ambystoma californiense)*, and a federally listed endangered animal, the arroyo toad *(Bufo californicus)*, are found on FHL. Yellow starthistle was first mapped on FHL in 1964, covering 1,660 acres. By 1998, it had spread to more than 20,000 acres (Osborne 1998). Yellow starthistle infestations are particularly dense in the areas along the San Antonio River and Nacimiento River riparian corridors, prime habitat for the arroyo toad (fig. 1).

Most of the areas within FHL that are heavily infested with yellow starthistle occur in or near arroyo toad habitat. In order to apply clopyralid within or adjacent to habitat of the endangered arroyo toad, the federal Endangered Species Act requires formal consultation between FHL and the U.S. Fish and Wildlife Service. Primary concerns that need to be addressed in the consultation



Jack Kelly Clark

Fig 1. **Major yellow starthistle infestations at Fort Hunter Liggett in southern Monterey County. *Right,* yellow starthistle.**

With the 1998 registration of clopyralid for wildland use in California, aerial application has become a common, effective control method for yellow starthistle.

are the potential for aerial applications of clopyralid to drift into streams and creeks, and the lack of information on the toxicological effects of clopyralid on amphibians, particularly toads.

Clopyralid toxicology tests have been conducted on several aquatic species including daphnia, minnows, sunfish and trout (Dow AgroSciences 1998). Clopyralid technical material was found to be practically nontoxic to fish and invertebrate species at LC_{50} levels (the lethal concentration that kills 50% of test animals) ranging from 104 to 232 parts per million (ppm; milligrams per liter). Formulations containing clopyralid were also nontoxic to fish and invertebrates with LC_{50} values ranging from 1,100 to 4,700 ppm. Although the toxicity is low for these organisms, there is no clopyralid toxicity data for amphibian species.

To address these concerns, we conducted two separate studies. As a model test animal for arroyo toad, the first study evaluated the susceptibility of larval Fowler's toad *(Bufo fowleri)* to formulated clopyralid (Transline) in a 96-hour static toxicity test. In a second experiment, we monitored herbicide drift from an aerial application of clopyralid for yellow starthistle control into adjacent buffered vernal pool and stream sites within a military use area on FHL. On the day of application, wind conditions were light (0 to 5 miles per hour [mph]) and blowing from the treated site toward the monitored creek. As such, this study provided an excellent opportunity to evaluate the drift potential of clopyralid into adjacent water sources.

Although the drift study took place within the context of a larger-scale yellow starthistle management study, the objectives of these studies were to (1) determine the effectiveness of a 98-foot (30-meter) buffer between the treatment perimeter and the adjacent stream; (2) monitor clopyralid aerial application for drift into adjacent water bodies; and (3) determine the toxicological effect of the formulated clopyralid solution on larval Fowler's toad.

Treatment location and parameters

The treatment site was located in Training Area 15, a 4,940-acre multiuse site at FHL. Within this area, an 1,110-acre grassland infestation of yellow starthistle was aerially treated by helicopter on the morning of March 19, 2001, with 6 ounces clopyralid (Transline) per acre (2.25 ounces a.e. clopyralid per acre plus 0.125% nonionic surfactant [First Choice]) at a spray volume of 7 gallons per acre. The helicopter was equipped with a 32-foot single boom approximately 75% of the rotor length and CP 0.078 30-degree deflector nozzles at 9-inch spacings. The application parameters produce a coarse spray per ASAE S-572 and USDA-ARS nozzle testing. Air speed was 70 mph and application altitude was 6 to 7 feet with a maximum of 10 feet in areas with no trees and 40 to 50 feet in areas with oak trees.

The treatment was applied under a wind speed of 0 to 5 mph. The treatment site was adjacent to Stony Creek, an intermittent stream flowing through the center of Training Area 15 at the time of application. The stream is located south of Lower Stony Reservoir and is a tributary to the Nacimiento River. The creek flows along the northwest boundary of the treatment area. The flowing water and land-based drift-monitoring sites were located along a 1,148-foot (350-meter) section of Stony Creek (fig. 2).

ArcView geographic information system (GIS) software was used to map treatment sites into shape files (NAD 1983 projection) for use with an on-aircraft Trimble navigational global positioning system (GPS) to help the pilot identify buffer zones and the edge of the treatment area. All application passes were recorded using GPS.

Within Training Area 15 there are five standing-water pools (fig. 2) exhibiting two or more definitive vernal pool characteristics: hydrology, geology, period of inundation or associated obligate wetland plant species. During spring the pools ranged in size from 0.012 acres (523 square feet/50 square meters for pool 1) to 1.6 acres (69,696 square feet/6,500 square meters for pool 5) and 8 to 15 inches deep, with an average depth of 10 inches. Pool 5, the largest, supports larvae of hybrid California-eastern tiger salamander (*Ambystoma* sp.)(E.R. Clark, U.S. Fish and Wildlife Service, personal communication). A 98-foot

Jason Jones

The arroyo toad is on the federal endangered species list, and is found at Fort Hunter Liggett. In the study, larval toads had a high tolerance to cloypyralid, and there was little risk of drift into aquatic areas when the herbicide was applied properly from the air.

(30-meter) buffer was established along Stony Creek and around vernal pools 1 to 4. This represented the typical distance between the water source and the beginning of the yellow starthistle infestation and was considered a sufficient safety buffer to minimize contamination of the water system. In one exception, however, a 656-foot (200-meter) buffer was established around vernal pool 5, due to tiger salamander larvae.

Before the herbicide treatment, but on the same day, control water and filter-paper samples were taken within the treated areas, in the vernal pools and within Stony Creek. On the day of application, winds were light (< 5 mph) from the southeast direction of the treated area toward the wetland sites. Samples were taken again following the herbicide application.

Monitoring parameters

Samples were placed in certified sterile 1,000-milliliter (ml) jars with Whatman 24-centimeter-diameter (circular) filter paper (MVTL Laboratories, New Ulm, Minn.). Water samples from Stony Creek were taken at eight time periods (three replicates per timing). A total of twenty-four 1,000 ml water samples were collected before treatment and then at 1, 2, 3, 4, 5, 10 and 15 minutes after the perimeter application pass closest to the stream. Vernal pool water samples were taken 1 hour after application. A 98-foot (30-meter) buffer was established between Stony Creek and the spray zone along approximately 3,937 feet (1,200 meters) of the east bank of Stony Creek as it runs adjacent to the treatment area (fig. 2). Four transects approximately 246 feet (75 meters) apart were established perpendicular to the creek. Transects ran from the water edge to the buffer/spray zone interface (fig. 2). Filter disks (Whatman 24-centimeter-diameter [circular] filter paper) were staked at 33-foot (10-meter) intervals along the four transects. The filter papers were pinned to the ground with three or four 10-inch bamboo skewers pushed through the paper. All filter-paper samples were folded and inserted into 500 ml sterile sample jars. Samples were retrieved 30 to 60 minutes after the area was treated.

Filter disks were also placed at four random locations within the treatment zone before the herbicide application to determine clopyralid concentrations. Eight samples were placed in the field.

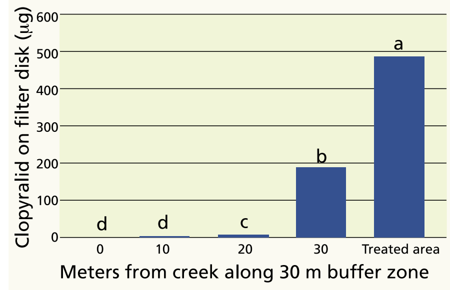


Fig. 3. Clopyralid detected within the treatment zone and 10-meter intervals along a 30-meter buffer between Stony Creek and on treatment area. Values reported at µg/filter disk; detection limit was 0.00125 µg. Bars with different letters represent significant differences at 95% probability.

Four samples were collected just prior to aerial application to serve as untreated control measurements and an additional four filter disks were retrieved 30 to 60 minutes after treatment. The disks were folded and inserted into sample jars that were quickly sealed and packed in dry ice; water and filter-paper analyses were conducted by MTVL Laboratories in New Ulm, Minn. The laboratory's method (specifics available upon request) can detect clopyralid residues in water down to the lowest validated level of 0.05 parts per billion (ppb; 0.05 μg/L); the lower detection limit for the filter-paper samples was 0.00125 μg.

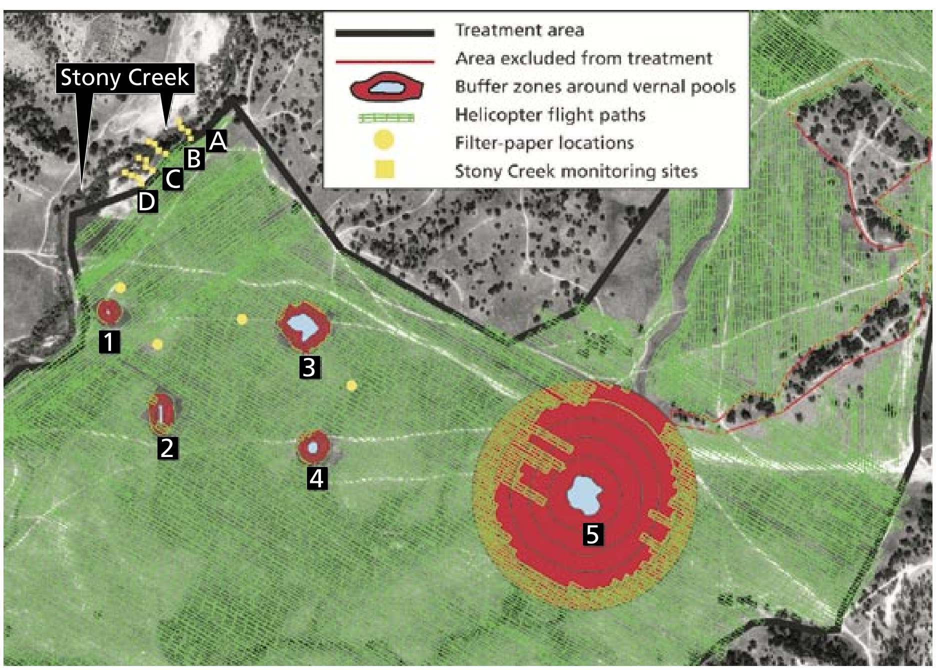


Fig. 2. Monitoring sites and aerial clopyralid applications at Fort Hunter Liggett. In upper left, Stony Creek transects A to D were monitored from the edge of the creek to 98 feet away (30 meters; edge of treatment area). Control samples on filter paper were taken from within the treatment area. Vernal pools 1 to 4 are shown with 98-foot (30-meter) buffers; vernal pool 5, the California tiger salamander breeding pool, has a 656-foot (200-meter) buffer. Helicopter flight paths are shown in relation to vernal pools and buffers zones.

Clopyralid drift to Stony Creek

Based on an application rate of 6 ounces clopyralid per acre, the expected concentration of clopyralid on each 9.5-inch- (24-centimeter-) diameter disk was 710 μg. However, in the four filter-paper disks within the treatment area, the average concentration of recovered clopyralid was 487 μg (standard deviation = 44 μg)(fig. 3). This represents 69% recovery from the expected clopyralid concentration, which could be due to calibration error, application variability or incomplete extraction in the laboratory evaluation.

The application of clopyralid was mapped using GPS (fig. 2). The GPS spray pattern corresponded closely with the designated buffer zone in the monitored site. The recovery of clopyralid dropped rapidly at greater distances from the treatment zone (fig. 3). At the edge of the treatment area (98 feet [30 meters] from the stream bank) the detected level of clopyralid was 61% lower than within the treatment zone. At 66 feet (20 meters) from the stream, clopyralid was reduced by 98.7% and at

The drift potential of aerially applied clopyralid was tested in and around vernal pools and streams at Fort Hunter Liggett, where yellow starthistle infests more than 20,000 acres.

the stream bank (approximately 98 feet [30 meters] from the treatment area) only 0.1% of the clopyralid concentration of treatment rate was detected. Clopyralid was undetectable in all samples taken in Stony Creek at all monitoring times (pretreatment and 1, 2, 3, 4, 5, 10 and 15 minutes after application). This suggests that a 98 foot (30-meter) buffer is adequate to prevent clopyralid drift into adjacent water systems, even in the presence of a 5-mph wind blowing from the treatment zone toward Stony Creek.

Clopyralid drift to vernal pools

Clopyralid was not detectable in vernal pools 1 and 4. The spray pattern from the GPS monitoring indicated that the buffer in vernal pool 1 was not treated (fig. 2). The average depth of the vernal pools was estimated to be approximately 10 inches (25 centimeters). Based on this estimate and the recovery value of clopyralid in the treatment zone (487 μg per disk), it was determined that a direct application of the herbicide into a vernal pool would yield an average clopyralid concentration of 42.0 ppb. In vernal pool 4, a portion of the northwest end of the buffer was accidentally treated, but this was in the downwind side and, consequently, no clopyralid was detected in the pool. In vernal pools 3 and 5, clopyralid was found, but only at the lowest detection limit (0.05 ppb), representing 0.1% of that expected from a direct application into the water body.

The buffer of vernal pool 3 was not treated, but the buffer zone of vernal pool 5 was accidentally encroached on a number of passes and applications were made as close as 131 feet (40 meters) from the vernal pool. Because of the potential presence of the tiger salamander, this vernal pool was supposed to have a 656-foot (200-meter) buffer.

Despite the encroachment, very little clopyralid was detected in the pool. Applicator error in vernal pool 2 accounted for herbicide treatment nearly at the waters edge. In this area, the pilot encroached into the buffer area upwind of the vernal pool. As a result, the concentration of clopyralid in this vernal pool was the highest of all the pools monitored (0.25 ppb). This represented a concentration of clopyralid that was only 0.6% of what would be expected with a direct application in the pool. Overall, the amount of clopyralid found in vernal pools was only 0.2% of that expected with a direct application over water.

A simulation drift model was used to compare field results with expected results of herbicide drift. Vernal pools 2 and 5 were chosen for the a EPA/SDTF (Environmental Protection Agency/Spray Drift Task Force) AgDRIFT model (Bird et al. 2002) because there was some deposition related to buffer encroachment. Input to the model used the clopyralid rate (6 ounces per acre), application parameters (2.5 to 4 mph wind speed and 8-foot spray height) and the pool's depth and size. The model does not consider wind variation and drift mitigation due to canopy foliage during application. Buffers were visually estimated from data provided through GPS maps and are therefore estimated averages. The model over-predicts deposition from actual field results (table 1) and is expected to be conservative for EPA assessments, but the differences between the model and field results are considered within reasonable environmental variations.

Toad toxicology experiment

Because the arroyo toad is a federally listed endangered species it could not be used in toxicology tests; instead, we used a related species (Fowler's toad) as a model. The California Department of Fish and Game's Aquatic Toxicology Laboratory in Elk Grove conducted toxicity testing. Larval toads were exposed to formulated clopyralid (Transline) in 96-hour static toxicity tests following established laboratory procedures (DFG 2000, 2001) and federal testing guidelines (US EPA 1993).

TABLE 1. AgDRIFT aquatic assessment estimates for clopyralid in two vernal pools

Vernal pool	Average pool depth	Estimated average buffer	Actual clopyralid detection	AgDRIFT estimate of clopyralid detected
	inches	*feet (m)*	*ppb*	*ppb*
2	9–10	66 (20)	0.25	0.7–0.85
5	9–10	492 (150)	0.05	0.1–0.14

TABLE 2. Survival of larval Fowler's toads after 96-hour exposure to clopyralid

Concentration	Larvae exposed	Larvae surviving	Survival*
ppm	*no.*	*no.*	*%*
Untreated control	40	40	100a
151	40	40	100a
313	40	36	90a
538	40	0	0b
700	40	0	0b
910	40	0	0b
1,030	40	0	0b

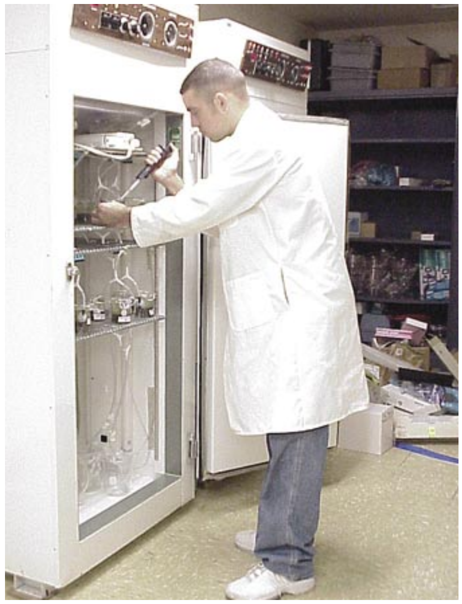
* Different letters following percent survival indicate significant difference (ANOVA, $P < 0.05$).

Larval toads (17 days old) were purchased from Northeastern Aquatics (Rhinebeck, N.Y.) and were delivered to the laboratory in good condition. After acclimation at 36°F (2°C) for 96 hours, 10 larval toads were loaded into 1-liter Pyrex test cups containing 250 ml of the test solution. Excluding the control, there were six test solutions ranging from 151 to 1,030 ppm (mg/L)(measured as technical clopyralid)(table 2). After the tadpole loading, the test cups were placed in environmental chambers. Random numbers were used to select the location of test cups within the chambers. Chamber temperatures were maintained at 72 °F ± 2°F (22°C ± 1°C) for the duration of the test with a photoperiod regime of 16 hours light and 8 hours dark.

To ensure a constant concentration of clopyralid, the treatment solutions were replaced on the second test day. Water quality (conductivity, temperature, pH and dissolved oxygen) was monitored daily in the test cups. Alkalinity, total hardness and toxicant concentrations were determined at the initiation of the experiment and 2 days after exposure in the original and replaced solutions. Test chambers were checked daily for tadpole mortality. Dead larvae were removed from the test chambers upon discovery.

Tadpole survival in the untreated control was 100% (table 2). Similarly, no larvae mortality was observed at the lowest treatment concentration of 151 ppm clopyralid. Fowler's toad larvae did not survive in test-solution concentrations of 538 ppm or higher. The 96-hour LC_{50} value for larval Fowler's toads was 413 ppm clopyralid. The U.S. EPA designates LC_{50} values greater than 100 ppm as "practically nontoxic" to nontarget aquatic organisms (Zucker 1985).

Using the highest concentration where no toxicological effect was observed (151 ppm) and assuming that under a worst-case scenario clopyralid was accidentally applied directly over water (10 inches [25 centimeters] deep) at the highest registered rate (10.7 ounces per acre) the clopyralid concentration in water would be 0.11 ppm. This would provide a safety factor greater than 1,370 for larval toads. When the clopyralid concentration obtained in the drift experiment is used (0.00025 ppm), the safety margin for larval toads is increased to greater than 600,000 (151 ppm/0.00025 ppm).



Kyle Emery tests tadpoles in an environmental chamber, which maintains constant temperature and humidity as well as a light-dark regime.

These findings provide direct evidence showing minimal drift movement of clopyralid off-site, despite an aerial application and a slight wind in the direction of the sensitive site. In addition, this is the first report demonstrating a high tolerance to clopyralid in larval toads, suggesting that a 98-foot (30-meter) buffer between the treatment zone and water sources is sufficient to provide a reasonable margin of safety to aquatic organisms, presumably including toad species.

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RESEARCH ARTICLE

Alternative techniques improve irrigation and nutrient management on dairies

Larry Schwankl
Carol Frate

Researchers measured water discharge into the field by placing plastic hydrants over alfalfa valves with a Doppler flow meter attached.

Many of the dairies in California's Central Valley use a water flush system for manure handling; the manure water is eventually mixed with freshwater and applied to cropland during irrigation. Good performance during irrigation applications is important due to the nutrients in the manure water. This project evaluated alternative management techniques (furrow torpedoes, surge irrigation and shortening furrow lengths) for improving irrigation practices on dairies. All three techniques reduced the amount of water required for irrigation. The project also investigated the impact of changing the timing of manure-water additions to the fresh irrigation water. Delaying the addition of manure water until the advancing fresh irrigation water had reached approximately 80% of the distance down the field improved nutrient-application uniformity and reduced nutrient applications.

Many of the more than 1,600 dairies in the Central Valley of California use a water flush system to clean manure from free-stall barns. This flush water is collected and held in ponds until it can be mixed with freshwater and applied to cropland as part of surface irrigation practices. The application of manure-water nutrients in excess of agronomically appropriate rates can result in loss of nutrients, often to deep percolation below the crop's root zone. Due to the high levels of nutrients in manure water, high efficiency and uniformity are important to assure a uniform distribution of nutrients during irrigation and to minimize the deep percolation of nitrates, which can pollute groundwater.

Furrow and border irrigation systems are commonly used with manure-water applications on dairies in the San Joaquin Valley. Sprinkler irrigation with manure water is seldom used due to odor and air pollution concerns, and is prohibited in some counties. Furrow and border irrigation systems are often inefficient due to over-irrigation and poor application uniformity. Tailwater — irrigation water that runs off the end of a field — that is not reused is one source of inefficiency. Tailwater containing manure cannot leave the grower's property, and the standard practice on dairies is to minimize its generation during irrigation. If tailwater is generated, a return system is often used to collect it for reuse.

Deep percolation is the major contributor to irrigation inefficiency on dairies, and over-irrigation often results when fields are too long. A certain quantity of irrigation water is required simply to advance water to the end of the field. This is the minimum amount of water applied per irrigation event, which often exceeds the amount of water required to refill the crop's root zone and results in inefficient irrigation.

A field project was undertaken during the summers of 2001 and 2002 to evaluate techniques for improving the irrigation and nutrient management of flood irrigation systems that apply manure water. Improved irrigation systems should apply water and the nutrients carried in water (water-run) more evenly on the field and allow application of the correct amount of water to match crop needs. Three irrigation-water management techniques — furrow torpedoes, surge irrigation and field-length reductions — were investigated on a Tulare County dairy. Another management strategy, manipulating the timing of manure-water additions to the fresh irrigation water, was evaluated on the same dairy.

Furrow torpedoes

Furrow torpedoes are steel cylinders, often filled with concrete, which are dragged in the furrow to break up soil clods and smooth the surface. They can allow water to advance across a field more quickly, resulting in improved irrigation uniformity and efficiency. Torpedo use is beneficial after field preparation or cultivation, but it is not

The application of manure-water nutrients in excess of agronomically appropriate rates can result in loss of nutrients, often to deep percolation below the crop's root zone.

effective if there is no cultivation to disturb the furrow between irrigations (Schwankl et al. 1992).

The impact of torpedo use for manure-water irrigations was evaluated by comparing three irrigation blocks of 25 torpedoed furrows each, with the same number of blocks and furrows that were not torpedoed. All furrows were 1,250 feet long. Water was supplied at the head of the field using an underground pipeline with alfalfa valves. Each block of 25 furrows — centered on an alfalfa valve — was bordered by berms running the length of the field. These berms kept the water from each alfalfa valve constrained to flow down the 25 furrows supplied by that valve. This is a common irrigation system for dairies in the San Joaquin Valley.

The preseason irrigation event was monitored. This irrigation is often inefficient because the soil has been extensively worked and has a high infiltration rate. A PVC hydrant with a discharge pipe out its side was placed over the alfalfa valve during irrigation. A Doppler flow meter was attached to the hydrant's discharge pipe to measure the flow rate and volume applied to each monitored block of furrows. The flow rates from the valves supplying areas being compared were kept as similar as possible, and records of total volume applied versus irrigation time were collected. There was some variation in inflow between furrows being supplied by a common alfalfa valve, but the water advance was fairly consistent between furrows. The rate that water advanced along the furrow was also monitored. Information on the advance rate and irrigation set-time was used to determine the intake opportunity times and the infiltrated water at locations within the field.

The irrigation set was changed soon after water reached the end of the field. Without a return system, care was taken to minimize tailwater runoff. Tailwater generated by furrows — in which water advanced faster to the end of the field — flowed a short distance into the tail end of "dry" furrows, which had not yet completed their water advance. Torpedo use was effective in reducing the applied water from 12.9 to 9.4 inches — a 27% reduction from continuous-flow irrigation (table 1). Water advanced faster across the field, resulting in a shorter irrigation set-time and less water applied. Torpedo use is not widespread in the San Joaquin Valley, primarily due to the difficulty and cost. The torpedoes are dragged behind a tractor and it is often difficult to turn at the end of the field with the torpedoes attached. Some growers have solved this problem by connecting the torpedoes to a sled so that they can be hydraulically lifted at the ends of fields. Because of these complications, furrows are often torpedoed as a separate equipment pass through the field — an added cost.

Furrow torpedoes are attached to a sled to ease turning at the end of the field.

Surge irrigation on dairies

Surge irrigation is the on-off cycling of water during irrigation. Water is allowed to run down a group of furrows and at some point (such as one-quarter of the way down the field), the water is moved to another group of furrows. While water is running in the second group of furrows, water in the first group of furrows is infiltrating and the furrows are "de-watering." When water in the second group of furrows has advanced to the same distance as the first group, water is switched back to the first group. As water is reintroduced to the first group of furrows, it advances across the wetted portion of the field very quickly and then slows down appreciably as it starts to advance across the dry soil. This on-off cycling of water is continued until water reaches the end of the field.

This practice can improve irrigation efficiency by advancing water across the field using less water — as compared to continuous-flow irrigation — due to an infiltration reduction on soil wetted by a previous surge cycle (Hanson et al. 1998). This infiltration-rate reduction is likely due to a sealing of the soil surface. Surge irrigation has not been previously investigated on fields irrigated with manure water. Manure water contains a substantial amount of fine solids, which was thought to have a significant positive impact on surge-irrigation performance.

Surge irrigation was evaluated by comparing two blocks of 25 furrows each irrigated with continuous flow; and four blocks of 25 furrows each surge-irrigated. Four surge cycles were used. Water was allowed to advance about one-quarter of the way down the field (300 feet), and then the water was transferred to another section of furrows. By the time the water was transferred back to the original section, water had infiltrated into the furrow. During the second surge, water was allowed to advance another one-quarter of the field (to 600 feet). Water was again transferred to another set of furrows. This continued for the third surge (advance to 900 feet) and fourth surge (advance to the end of the field — 1,250 feet).

TABLE 1. Effects of surge irrigation, furrow torpedoes and field length on furrow-irrigation performance

Block	Torpedoed	Flow	Applied water at 1,250 ft.	Applied water at 600 ft.
			inches	
1	No	Continuous	12.9	7.1
2	No	Surge	9.1	5.4
3	No	Surge	8.4	5.2
4	Yes	Surge	7.8	5.0
5	Yes	Surge	10.5	4.8
6	Yes	Continuous	9.4	4.3

Sulfur fertilizer has been added to this advancing front of water, to act as a visual tracer. The tracer has not been added to water in the furrows at the top and bottom

Surge irrigation was effective in reducing the amount of water required to irrigate nontorpedoed furrows. Applied water was reduced from 12.9 to 9.1 inches — a 30% decrease, or from 12.9 to 8.4 inches — a 35% decrease (table 1). For torpedoed furrows that were surge-irrigated, results were mixed. Applied water on one section of furrows was reduced from 9.4 to 7.8 inches — a 17% decrease (table 1). On another block of 25 furrows, the torpedoed/surge-irrigated furrows required more water, 9.4 versus 10.5 inches — a 12% increase (table 1). Surveying the field slope on the monitored blocks revealed that block 5 had an uneven slope, which likely affected the amount of applied water required. From these results, it is not conclusive that using surge irrigation on torpedoed furrows is beneficial. It is likely that the excess applied water avoided by using surge irrigation or torpedoes would go to deep percolation, which could leach nitrates.

Surge irrigation would therefore seem to be a natural practice for growers to adopt, but the furrow systems on most dairies do not lend themselves to it. Surge irrigation using freshwater alone is done using gated pipe and an automatic surge valve. Dairies seldom use gated pipe because the manure solids and trash (such as weeds and baling twine) in the manure water clog the discharge openings. Instead, dairies often use alfalfa valves, which discharge water into a block of furrows. An added complication is that the automatic surge valve has an internal, motorized, butterfly valve that could become entangled with trash in the water. To use surge irrigation on dairies now would require irrigators to manually open and close alfalfa valves — a significant increase in labor and management costs.

Irrigations occur day and night. Using surge irrigation at night is more complicated than during the day, when advance rates can be more easily observed. However, once an irrigator determines the advance times on a field, surge-irrigation switches could be made on an irrigation-time basis. This assumes a constant irrigation flow-rate to each block of a field, which can be difficult to achieve since many ranches irrigate multiple fields at the same time.

Reducing field lengths

San Joaquin Valley field lengths vary widely, but one-quarter mile is common. This is often too long to allow water applications that match the water needs of the crop. The minimum irrigation-application amount is determined by the amount of water needed to advance water to the end of the field. For example, if 6 inches of water is required but the crop water use since the last irrigation has been 4 inches, at least 2 inches of water would be lost to deep percolation (assuming no tailwater runoff). If nutrients are available to be leached, the excess water could be the vehicle for carrying them below the crop's root zone. Shortening the field length allows a lesser irrigation amount to be applied during an irrigation set and allows that amount to more closely match the water depleted from the crop's root zone, thereby increasing irrigation efficiency. Irrigation uniformity is also improved in shorter fields.

Evaluation of irrigation-system performance for shorter field lengths was relatively simple since the applied water, advance time and other necessary information was available as a subset of the field-evaluation data that was collected as part of the continuous/surge flow evaluations. The 1,250-foot furrows were evaluated to see how much water would be required if field length was reduced to 600 feet (table 1). Applied irrigation amounts could be reduced by 35% to 55% when field lengths were reduced from 1,250 to 600 feet.

Reductions in field length have the greatest impact on irrigation performance, but they are also the most costly and inconvenient to implement. To reduce a one-quarter-mile-long field to two one-eighth-mile fields would require a new pipeline ($15,000 to $20,000 for a 40-acre field), a new road (a capital cost and land lost from production) and possibly new tailwater-collection facilities. Shorter field lengths are also a significant inconvenience when equipment is moved through the field, with consequent impacts on field preparation, cultivation, pest and weed control, and harvest activities.

Timing of manure-water additions

Field tests were done to manipulate the timing of manure-water additions to irrigation water. The objectives were: (1) to improve the uniformity of nutrient applications, and (2) to provide a method for applying smaller amounts of nutrients per irrigation event as compared to adding manure water during the entire irrigation event, which is currently the most common practice. This strategy of changing the timing of manure-water additions hinges on infiltration characteristics, which vary during irrigation. The infiltration rate is high when water first comes into contact with a dry soil and then decreases, often significantly, until a final, relatively constant intake rate is reached. Due to the time required for water to advance across the field, water is in contact with the soil (intake opportunity time) at the head of the field for a significantly greater time than at the field's tail end. The result is more infiltrated water at the head of the field than the tail. The same is true of nutrient applications if manure water is added continuously to the irrigation water.

To apply a lower nutrient amount during a continuous irrigation by using manure water with a high nitrogen concentration, a smaller flow-rate of manure water must be added to the irrigation water. This is often incompatible with the large manure pumps and pipelines designed for high flow-rates that dairies currently have. Running small flow-rates of manure water through large pipelines can result in settling and clogging of the pipeline.

We evaluated multiple irrigation events at the Tulare County commercial dairy. For an initial visual evaluation, a tracer (sulfur fertilizer) was added to the irrigation water at various delayed times during the irrigation event. The sulfur fertilizer turns the irrigation water milky in appearance and can be visually tracked as it moves down the furrow. The sulfur fertilizer was not used to trace infiltrated nutrients into the soil profile. From monitoring the tracer, it became evident that nutrient additions to the irrigation water could begin quite late in the irrigation set and still have time to advance to the end of the field before the end of the irrigation set.

From these tracer tests, we determined that the addition of manure water would start when clean irrigation water had advanced approximately 900 feet along the 1,250-foot-long field.

TABLE 2. Irrigation evaluation results of manure-water irrigation strategies (furrow-irrigated, 1,200 ft. long)

Nutrient application strategy	Average irrigation	Irrigation uniformity (DU)	Avg. manure water infiltrated	Manure-water uniformity (DU)	Nitrogen applied
	inches	*%*	*inches*	*%*	*lb/ac*
Manure water added during entire irrigation	7.1	64	7.1	64	242
Manure water started when freshwater advance = 900 ft.; shut-off when advanced to end of field	7.1	64	2.5	69	86
Simulation 1 Manure water started when freshwater advance = 900 ft.; shut-off = end of field advance + 1 hr.	7.6	70	3.0	69	102
Simulation 2 Manure water started when freshwater advance = 1,000 ft.; shut-off when advanced to end of field	7.1	64	0.9	91	31
Simulation 3 Manure water started when freshwater advance = 1,000 ft; shut-off = end of field advance + 1 hr.	7.6	70	1.4	88	49

As a result, the advancing front of the manure-water/freshwater mix caught the advancing front of the freshwater at the 1,050-foot furrow distance. It took the clean irrigation water 4 to 5 hours to advance to 1,050 feet, but it took the delayed manure-water advancing front less than 1 hour to reach the 1,050-foot mark.

Water samples were collected at frequent intervals (such as 15 minutes, but sometimes modified to more accurately measure water-quality changes) and at multiple locations along the furrow. These water samples traced the movement of the manure water along the furrow and provided the spatial and temporal distribution of water quality during the irrigation event.

RBC flumes were placed in furrows to monitor furrow flow-rate. The field was surveyed and its slope was determined. Advance-recession measurements were also gathered. The results from the irrigation evaluation were used to provide inputs to a two-point Volume Balance furrow-irrigation model (Walker and Skogerboe 1987), to determine infiltrated water amounts along the furrow and the irrigation uniformity.

The results of delaying additions of manure water to the irrigation water were promising: not only could a lesser amount of nutrient be applied using the existing manure-water application equipment, but the nutrients could also be applied more uniformly.

Water quality

Nitrogen and ammonium are found in manure water and can pollute groundwater if applied at levels too high and then leached through the soil profile. The fresh irrigation water/manure-water mix used for irrigation had approximately 100 milligrams per liter (mg/l) ammonium (NH_4–N) and 150 mg/l total nitrogen. For example, nitrogen samples taken 30 minutes after manure water traveled 900 feet along the field recorded the following ammonium (mg/l) and total nitrogen (mg/l) levels: head of field, 101 and 155; 300 feet along field, 106 and 155; 600 feet along field, 107 and 131; and 900 feet along field, 101 and 139. There was little change in ammonium content and a slight change in total nitrogen of the water along the furrow. As is common with dairy manure-waters, there was no nitrate in the manure water because manure ponds are anaerobic (oxygen-free). The manure water used for irrigation was relatively low in solids since the dairy had a solids separator and a multi-pond manure-handling system.

For this manure water, the majority of the nitrogen nutrients were tied up in the ammonium form and in the organic form as small particles that stay in suspension. The constant nitrogen content of the irrigation water along the furrow may not hold for manure water high in large particles, which settle out at the head of the field. In such cases, it is possible that the organic nitrogen content of the water would decrease more significantly as it moves down the furrow.

Infiltration, irrigation uniformity

In order to gauge infiltration and irrigation uniformity, we monitored an early-season irrigation event following a cultivation. Water advanced across the field in approximately 5.5 hours. The average irrigation depth applied was 7.1 inches with a distribution uniformity (DU) of 64% (table 2). As with many dairies in Tulare County, the irrigation system was operated to minimize tailwater runoff. Therefore, once water advanced to the end of the field, it was allowed to run only a short time before the irrigation set was switched. As a result, the top end of the field received substantially more infiltrated water than the tail end. For the monitored irrigation event, the head of the field received approximately 9.4 inches of infiltrated water while the tail end received approximately 3.1 inches.

If manure water had been added to the irrigation flows during the entire irrigation event, the uniformity of nitrogen application would have been the same as the water application uniformity — 64%. The top end of the field would have received significantly more nitrogen than the tail end. Adding manure water during the entire irrigation event would have resulted in the field receiving an average of 242 pounds of nitrogen per acre, which is generally considered to be excessive for a single irrigation event (table 2).

When manure water was added to the irrigation water after freshwater had advanced 900 feet along the furrow, the manure-water application uniformity was increased from 64% to 69%. However, at least as importantly, the average nitrogen application to the field was reduced from 242 to 86 pounds per acre (table 2), a level more appropriate for nutrient management.

With the field data available for model verification, the following simulations of other irrigation and manure-timing strategies were investigated using a two-point Volume Balance model.

Simulation 1. Manure-water additions began when freshwater reached 900 feet along the furrow. Irrigation water was shut off 1 hour after it reached the end of the field. This strategy would result in a nutrient application uniformity nearly the same as the irrigation uniformity (69% versus 70%)(table 2), but the average nitrogen application amount is reduced from 242 pounds per acre for the continuous manure-water addition strategy to 102 pounds per acre for this delayed manure-water addition practice.

Simulation 2. Freshwater was allowed to advance 1,000 feet along the furrow before manure water was added to the irrigation water. The irrigation supply was shut off shortly after water reached the end of the field. The result of this practice would be a small amount of nitrogen (31 pounds per acre) applied to the field very uniformly (DU = 91%). This is a good strategy if frequent, small applications of nitrogen are desired.

Simulation 3. In this delayed manure-water addition strategy, manure water was added to the irrigation water after freshwater had advanced to 1,000 feet. Irrigation was allowed to continue for 1 hour after water advanced to the end of the field. This strategy allows the application of a limited amount of nitrogen to the field (49 pounds per acre) while applying it with a high uniformity (88%). Of all the strategies evaluated, this is preferable since it increases both the irrigation and nutrient application uniformities (table 2) compared to adding manure water during the entire irrigation event, which is stopped when water reaches the end of the field.

Delayed addition of manure water holds promise as a means of improving nutrient application uniformity and of applying less nitrogen during an irrigation, while still using existing high-flow-rate manure-water pumps and pipelines. One disadvantage of delaying manure-water applications is that there is a delay between when manure-water pumps are turned on and when manure water reaches the irrigated field. For the field evaluated in this study, that delay was approximately 20 minutes. Furthermore, it is quite common for dairies to irrigate multiple fields at the same time, often at different locations on the dairy and utilizing complex piping systems, to deliver the water. This makes delayed manure-water additions, as well as any form of manure-water nutrient management, a complex task.

Reducing applied irrigation water

The three irrigation water-management techniques — furrow torpedoes, surge irrigation and shortening field lengths — were all effective in reducing the amount of applied water per irrigation. Furrow torpedoes reduced the applied water by approximately 25% and surge irrigation by 15% to 35%. Field-length reductions were also effective. Splitting a one-quarter-mile field into two one-eighth-mile fields could reduce the applied irrigation water by 35% to 55%.

The normal practice for applying manure water to a field is to add it to the freshwater during the entire irrigation event. Delaying addition of manure water until the advancing freshwater has reached 900 feet along a 1,250-foot field resulted in an increase in distribution uniformity (64% vs. 69%) of the manure-water application and a decrease in applied nitrogen (242 versus 86 pounds per acre) as compared to the continuous addition of manure water. Simulation of other delayed manure-water addition strategies indicated that nutrient application uniformity could be increased to nearly 90% while applying 30 to 50 pounds per acre of nitrogen during an irrigation event.

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RESEARCH ARTICLE

Accuracy of cotton-planting forecasts assessed in the San Joaquin Valley

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In the first evaluation of its kind, we found that the UC Cooperative Extension (UCCE) 5-day degree-day forecast for cotton-planting conditions performed well in Bakersfield and Fresno when compared with the actual, observed temperatures from 1998 to 2002. In most cases, the forecast provided timely advice during the critical cotton-planting period. On average, only 7% of the forecasts failed to predict unfavorable conditions. Better-than-expected weather occurred 9% of the time when unfavorable conditions were forecast. On average during the 22 planting days of March (beginning March 10, the first allowable planting date in the San Joaquin Valley), 2.5 days (11%) were incorrectly forecast to have better-than-unfavorable planting conditions. In April, the cotton-planting forecasts were more reliable, with only 1 day out of 30 (3%), on average, that may have required replanting because of unpredicted, unfavorable conditions.

Steve Mendenhall, National Weather Service

The National Weather Service collects data at a series of weather stations in California, to produce air-temperature forecasts that are used by UC Cooperative Extension to calculate "degree-day" forecasts for cotton growers in the southern Central Valley.

Cotton production requires a relatively long period (190 to 210 days) of warm temperatures. The highest cotton yields occur when cotton is planted early under favorable conditions. Many factors influence the success of any particular cotton-planting decision, including soil temperature, seed vigor, air temperature, planting depth, soil moisture, level of soil-borne diseases, fungicide seed treatments and soil salinity.

Planting cotton involves risk. If several cold or wet days follow planting, then plant populations may be too low, requiring growers to replant. It would seem that cotton growers could reduce their risk by waiting to plant until later in the spring, when conditions are warmer, but this approach does not work. Spring weather is variable in any given year, with favorable planting periods scattered throughout March and April. If growers delay, there may not be enough good planting days left in April. Waiting until later to plant also reduces the time needed for plant growth. An earlier planting adds no additional cost and may mean earlier fruiting and increased yields.

Historically, in California and across the U.S. Cotton Belt, soil temperatures at planting have been a primary tool for timing cotton-planting decisions. Since soil temperatures vary greatly throughout the day and with soil depth, the time and method of taking soil temperatures has been standardized. The accepted standard for planting cotton in California is at least 58°F soil temperature measured at 8 a.m. at a 6-inch depth in the center of a cotton bed (Johnson-Hake et al. 1996). Until the late 1980s, cotton growers primarily evaluated soil moisture and soil temperatures in the seed bed, then planted during warmer and drier periods of weather with good soil temperatures, and avoided periods when cold weather was predicted soon after planting. With the advent of degree-day forecasting in the late 1980s, growers began timing their planting using this new tool as well.

Degree-days and cotton planting

Cotton is an important crop in California, grown on 870,000 acres — primarily in the southern San Joaquin Valley — for a total value of $658 million in 2002 (CDFA 2003). In 1987, UC Cooperative Extension (UCCE) introduced a cotton-planting tool using a 5-day degree-day summation (Kerby et al. 1989). This tool provides an indication of the risk to germinating cotton seed based on forecasted air temperatures. Sometimes called heat units, degree-days are the integration of time and temperature above the known developmental baseline temperature of an organism for each day. One degree-day is 1 day (24 hours) during which the average air temperature is 1 degree above the baseline temperature (also known as the "lower developmental threshold temperature") that is associated with consistent growth for the organism. The 5-day degree-day forecast for cotton planting was developed to quantify the effects of expected weather in order to increase the chances of a successful planting.

Farm Advisor Kater Hake and Specialist Tom Kerby developed this forecasting tool during the mid-1980s (Kerby et al. 1989). It combined a relationship between air temperature and quality of seed on stand establishment, and utilized knowledge of cotton's decreased yields due to chilling injury. The degree-day summation uses a basal developmental threshold of 60°F (cotton growth occurs at 60°F and above) and a single triangle calculation (to estimate air temperature for each hour of the day); it accumulates degree-days based on forecasted high and low temperatures during the 5 days following planting. These researchers established four categories for predicting planting conditions (and hence cotton establishment) based on the forecasted degree-days (table 1A). For example, ideal planting conditions are when the degree-day summation for the 5-day period beginning on the day of planting is greater than 20 degree-days.

For many years, the National Weather Service (NWS) in Hanford calculated the cotton 5-day degree-day forecast for Bakersfield and Fresno. This information was broadcast daily over the National Oceanic and Atmospheric Administration (NOAA) Weather Radio throughout the San Joaquin Valley during the cotton-planting season. When the NWS stopped providing the forecast of cotton-planting conditions, UC cotton advisors and specialists asked the UC Statewide IPM Program (UC IPM) to calculate the 5-day degree-day summations.

In March 1997, the UC IPM information systems group began posting the 5-day degree-day forecasts on the UC IPM Web site (www.ipm.ucdavis.edu) each day during cotton-planting season. The page includes a table displaying the forecasts of maximum and minimum air temperature for the next 5 days (including the day of posting) for Bakersfield and Fresno, the daily degree-days calculated from the forecasts, and the total degree-days for the 5-day period, as well as information on how to use the planting forecast. The air-temperature forecasts used in the calculations are generated by the Hanford office of the NWS as part of their standard forecasts for Fresno and Bakersfield. Since the UC IPM Web page is usually prepared after the minimum temperature has occurred, the observed lows for the morning (as reported for the Fresno and Bakersfield airports) are used as the minimum temperatures for the first day of the period. The page is updated each day from March 10 through April 30. (March 10 is the first allowed planting day to provide for a pink bollworm host–free period.)

In 2000, a survey of cotton growers' IPM practices (Brodt et al. 2003) found that 87% used the degree-day forecast in their cotton-planting decisions. This usage was reflected in the number of contacts recorded for the forecast Web site. During the 2000 planting season, the site was accessed 6,343 times (Strand 2000). In addition to this direct access, many consultants and pest control advisors provide this information to clients. This survey provided evidence that the cotton 5-day degree-day forecast is commonly used by California growers to help make planting decisions.

The purpose of our study was to evaluate the accuracy and reliability of the planting forecasts for Bakersfield and Fresno compared to observed air-temperature data for 1998 through 2002. For each date's planting-conditions forecast, the total degree-days for that date and the next 4 days were calculated and the resulting planting-conditions category was determined (table 1B). For comparison, we used data from

TABLE 1A. Example of 5-day degree-days forecast (°D) and cotton-planting conditions (°F) for Fresno and Bakersfield

	Fresno		Bakersfield	
Date	Degree-days	Temp. min./max.	Degree-days	Temp. min./max.
	°D	*°F*	*°D*	*°F*
April 6	2.9	50/71	3.4	51/72
April 7	1.7	49/68	1.9	48/69
April 8	0.5	49/64	0.7	52/64
April 9	0.4	44/64	0.9	45/66
April 10	2.7	45/72	2.9	47/72
Total	**8**		**10**	

TABLE 1B. Example of cotton-planting forecast provided on UC IPM Web site

Forecast	Planting conditions
> 20 °D*	Ideal
16–20 °D	Adequate
11–15 °D	Marginal
≤ 10 °D	Unfavorable

* Degree-days.

UC IPM resources

The UC Statewide IPM Program Web site has a degree-day calculator that lets any user accumulate degree-days for specific pests, plants and thresholds. The program can use data stored in UC IPM's extensive weather database, or weather data entered by the user.

The weather database holds temperatures, rainfall, solar radiation, relative humidity and wind data for more than 150 California stations that report daily, in addition to 150 long-term climate stations. About 120 of the daily stations, most in agricultural locations, are from the California Department of Water Resources CIMIS (California Irrigation Management Information System) program (**www.cimis.water.ca.gov**).

Growers can get the forecast of cotton-planting conditions from the UC IPM Web site at **www.ipm.ucdavis.edu/WEATHER/** or use their local forecast in conjunction with the degree-day calculator.

Cotton requires particular conditions for successful planting. If several cold or wet days follow planting, plant populations will be reduced and expensive replanting may be required.

the 5-day summations of degree-days calculated with the UC IPM degree-day calculator, using daily maximum and minimum air temperatures measured by NWS Automated Surface Observing Systems at the Fresno and Bakersfield airports. This data is routinely reported to NOAA's National Climatic Data Center (NCDC), then retrieved and stored on the UC IPM Web site as Fresno.C and Bakrsfld.C (NCDC station numbers 3257 and 0442, respectively). Although data from weather stations located on agricultural sites is available on the UC IPM Web site, the airport stations were selected for this study because the NWS verifies the accuracy of their Fresno and Bakersfield forecasts against measurements at these two locations. The observed category for cotton-planting conditions (tables 1A and 1B) was determined from the 5-day degree-day summation.

During this 5-year period, 516 maximum and minimum air-temperature forecasts (four forecasts were missing) were used to determine the forecasted category for cotton-planting conditions. Then these were compared to the actual (described here as "observed") air-temperature data and resulting planting-conditions category for the dates. A chi-square test was applied to the different forecast-to-observed comparisons, to test for goodness-of-fit or independence.

Accuracy of the forecasts

Predicting the weather at any time of year can be a challenge, but predicting 5 days of maximum and minimum air temperatures in the spring can be particularly difficult due to the variable nature of weather at that time. Fortunately, the 5-day degree-day forecast must only predict the correct planting-conditions category, a five or 10 degree-day range (table 1B), rather than be strictly accurate to the actual degree-day total. This is particularly helpful when the 5-day degree-day forecast is unfavorable (10 degree-days or less) or ideal (more than 20 degree-days).

Over the 5 years, accuracy for the Fresno and Bakersfield locations was similar, differing only by 1% or 2% within each category, so the following analysis is based primarily on averages of the two locations. The 5-day degree-day forecasts predicted the correct category (based on comparison with observed temperatures) 75% of the time (table 2). The forecasts significantly overestimated the suitability of conditions for planting ($P = 0.0011$, $n = 84$ of 516 total), yet underestimated the planting-conditions category only 57% as often ($n = 48$ of 516 total). The forecasted planting-conditions category was one higher or lower than the observed category 20% of the time, while it was two categories lower or higher in only 5% of the cases. During the 5-year period, it was never three categories higher or lower.

These numbers give a measure of the overall accuracy of the 5-day high and low temperature forecasts, while taking into account that the cotton-planting forecast needs only to fall within a five degree-day range to be very useful to cotton farmers. The more often the forecast and observed degree-day summations are in the same category, the more useful it is for a grower making planting decisions. Forecasting the correct planting-conditions category 75% of the time provides a very useful tool.

When the forecast underestimated the observed category, actual air temperatures and resulting planting conditions were more favorable than predicted. This occurred in 9% of the forecasts. If the forecast indicated unfavorable or marginal planting conditions, this error would probably result in delayed cotton plantings. However, delaying planting by a few days is not a serious error, especially if planting can be resumed during better-than-expected conditions.

When the forecast overestimated the planting category, conditions were

TABLE 2. Five-year (1998–2002) comparison of forecast versus observed 5-day degree-day cotton-planting conditions for Bakersfield and Fresno, March 10 through April 30

	Bakersfield		Fresno	
Planting-conditions category	Days	Frequency	Days	Frequency
	n	%	*n*	%
Equal	190	74	195	76
Forecast one category lower	20	8	22	9
Forecast two categories lower	2	1	4	2
Forecast one category better	29	11	34	13
Forecast two categories better	17	7	3	1

TABLE 3. Percentage of observed planting days for each planting-condition category for Bakersfield and Fresno, 1998–2002

Planting conditions category	March		April	
	Bkrsfld.*	Fresno	Bkrsfld.	Fresno
	. . . . %			
Unfavorable	47	46	28	29
Marginal	17	15	9	7
Adequate	12	12	8	12
Ideal	24	26	55	53

* Bakersfield.

TABLE 4. Observed cotton-planting conditions by year, March 10 to April 30

Year	Unfavorable		Marginal		Adequate		Ideal	
	Bkrsfld.*	Fresno	Bkrsfld.	Fresno	Bkrsfld.	Fresno	Bkrsfld.	Fresno
	. . . . no. days							
1998	25	26	4	3	4	3	19	20
1999	32	32	2	0	4	6	14	14
2000	9	4	14	13	5	10	24	25
2001	15	17	6	3	6	7	25	25
2002	13	15	6	8	6	5	27	24
Average (1998–2002)	19	19	6	5	5	6	22	22
Average (30 years)	7	20	15	4	5	7	25	21

*Bakersfield.

less favorable to cotton planting than predicted. This error is potentially more serious than underestimation and occurred 16% of the time. The most serious error occurred when the predicted category was in the marginal or adequate categories, but the observed category was unfavorable. This error occurred in 7% of the cases during the 5-year period. If cotton was planted under these conditions, it would likely need to be replanted, resulting in potentially lower yields due to a shorter season, and additional management expenses such as irrigation, plant growth regulators and late-season insecticides. For example, most San Joaquin Valley cotton is planted in April and it can take from 10 to 20 days after the first planting to make a decision about whether to replant. Each day's delay after April 15 can result in a 1% to 2% yield reduction per day (Johnson-Hake et al. 1996; Wright et al. 1998).

Degree-day distribution

On average at both locations, most of the observed 5-day degree-day totals during the planting period fell into the extreme categories of unfavorable or ideal (table 3). Averaged over both locations, for 72% of the days in March and 82% of the days in April, the observed degree-day totals were in these extreme categories. Observed totals for only 28% of the March planting days and 18% of the April planting days were in the adequate and marginal categories. April had more than twice the ideal planting days compared with March, and the distribution of the categories significantly differed between the months ($X^2 = 48.4$, $P < 0.0001$).

As expected with variable spring weather, there were significant year-to-year variations ($X^2 = 85.7$, $P < 0.0001$) in the distribution of observed degree-day categories. The total number of days in the unfavorable category varied from 4 days in Fresno to 32 days in both Bakersfield and Fresno over the 5-year period (table 4). The ideal category had a smaller range of 14 days for both Bakersfield and Fresno to 27 days for Bakersfield, with an average of 22 days per year. The average degree-day distribution between the four categories for this 5-year period was similar to the 30-year averages for the Bakersfield and Fresno NOAA stations (table 4), except for the unfavorable and marginal planting conditions for Bakersfield.

The 5-day degree-day forecast for cotton planting was developed to quantify the effects of expected weather in order to increase the chances of a successful planting.

Young cotton plants need the right combination of soil temperature, seed vigor, air temperature, planting depth, soil moisture and other factors to thrive.

Unpredicted unfavorable weather

The most serious error occurred when the forecast failed to predict unfavorable planting conditions. There was no significant difference ($P = 1.0000$) between the errors for Bakersfield and Fresno. These errors averaged 3.5 days per year (table 5).

There was significant ($X^2 = 66.9$, $P < 0.0001$) year-to-year variability (table 5). The forecast failed to predict the occurrence of unfavorable planting condi-

TABLE 5. Number of days when better-than-unfavorable planting conditions were forecast, but unfavorable conditions were observed

Years	Months	Bkrsfld.*	Fresno	Average
		. . . . *no. days*		
1998–2002	March-April	3.8	3.2	3.5
1998	March-April	3.0	3.0	3.0
1999	March-April	3.0	3.0	3.0
2000	March-April	7.0	4.0	5.5
2001	March-April	4.0	5.0	4.5
2002	March-April	2.0	1.0	1.5
1998–2002	March	2.6	2.4	2.5
1998–2002	April	1.2	0.8	1.0

* Bakersfield.

In California, cotton is planted between March 10 and the end of April to maximize yield and provide for an as-early-as-possible harvest, *above.* In the 5 years studied, the 5-day degree-day forecast was a reliable predictor of actual cotton-planting conditions.

tions on only 1 day in Fresno during the 2002 planting period, compared with 7 days in Bakersfield in 2000.

On average over the 5 years, 2.5 and 1.0 of the days predicted for better-than-unfavorable planting conditions in March and April, respectively, were actually unfavorable planting days (table 5). Because there are only 22 potential planting days in March (March 10 to 31) but 30 days in April, a potential March planting day is three times more likely than one in April to be forecast for better-than-unfavorable, but have unfavorable planting conditions ($X^2 = 19.5$, $P < 0.0001$). Planting on days with incorrectly forecast better-than-unfavorable conditions can require subsequent replanting and increase production costs, while eroding grower confidence in the forecast.

The planting-condition categories take into account the effects of seed quality on cotton stand establishment (Kerby et al. 1987). With high-quality seed, planting during cooler conditions is less risky than when seed quality is marginal. Also, the cost of replanting when this error occurs may be more than offset by the higher yields typically obtained with successful earlier planting.

By planting only on days in March with ideal category forecasts, growers can avoid negative results from the forecasts' tendency to overestimate conditions, since unfavorable conditions were never observed when the forecasts were in the ideal category. Over the 5-year period, on 25% of the potential planting days in March there were ideal planting conditions.

In April, planting cotton during unpredicted unfavorable conditions — and then having to replant — is more expensive, due to increased production costs and lower yields. Ten to 20 potential growing days may be lost while the grower decides whether replanting is necessary. Fortunately, on average, this situation occurred on only 1 out of 30 days in April.

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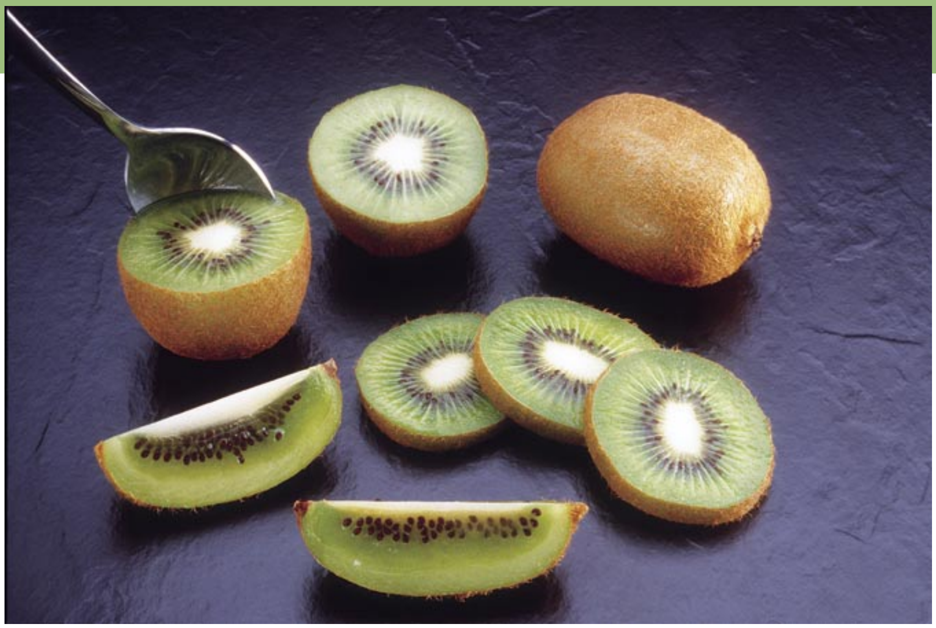
RESEARCH ARTICLE

California handlers describe marketing issues for organic kiwifruit

Hoy F. Carman
Karen M. Klonsky



California Kiwifruit Commission

About 4,500 acres of kiwifruit is grown in California. The crop lends itself to organic production, as there are currently few major pest or disease problems.

California kiwifruit is one of several commodities with a federal marketing order covering both conventional and organic products. Organic kiwifruit handlers were asked for their views on marketing issues for organic kiwifruit and how they differ from those for conventional kiwifruit. Organically produced kiwifruit accounted for 6.1% of total 2001-2002 California kiwifruit production. There are several differences between organic and conventional kiwifruit. The average size of organic kiwifruit is smaller than conventional kiwifruit; sales tend to occur later in the marketing year; there are more intermediaries (middlemen) in the marketing channel; and a larger proportion of organic product is packed in smaller shipping containers. The traditional price premium for organic product is decreasing as organic production increases, and it is not unusual for organically produced kiwifruit to be sold as conventional fruit in conventional marketing channels. Product appearance is becoming more important to consumers of organic fruit, who are now less willing to pay premium prices for cosmetically challenged product.

Organic fruit production and marketing is a fast-growing niche that is beginning to utilize traditional channels to reach an expanding market segment. As organic production grows and consumer preferences change, marketing practices will evolve. Many California commodities have established government-sponsored and producer-financed marketing programs that cover both organic and conventional production. California has federal and state marketing-order programs, commodity commissions and councils to assist in marketing agricultural products. A study of marketing issues associated with federal marketing orders for organic kiwifruit, almonds and winter pears surveyed all organic handlers for these crops (Carman et al. 2004). We report on the results for California organic kiwifruit.

California kiwifruit producers are well organized to market their crop. They secured the California legislature's approval of the California Kiwifruit Commission (CKC) in 1980 and voted to establish a federal marketing order for kiwifruit in October 1984. The CKC authorizes promotion and research activities, which are funded by an assessment on all shipments of California kiwifruit. The federal marketing order, administered by the Kiwifruit Administrative Committee (KAC), established mandatory minimum quality standards for grade, size and maturity that were first used for California kiwifruit during the 1987-1988 marketing year. These quality standards were extended to imports of fresh kiwifruit in 1990. Individual handlers pay mandatory inspection fees, and KAC activities are financed by an assessment on all shipments of California kiwifruit. Based on reported sales, California kiwifruit growers paid total assessments of approximately $524,500 in 2000-2001 and $433,200 in 2001-2002. The majority of these funds were used by the KAC for promotional activities.

California kiwifruit acreage

California kiwifruit plantings began during the 1960s, and commercial production was established in the early 1970s. Kiwifruit is a perennial vine crop that typically requires 4 years before the first crop and another 4 years to reach full production. The California Agricultural Statistics Service (CASS 2002) first reported kiwifruit acreage data in 1974, consisting of 56 bearing acres and 349 nonbearing acres. Initially, a combination of high yields for mature acreage and high prices encouraged

Organic kiwifruit has commanded a premium market price, although the premium has decreased over time as production and imports have increased.

plantings of the new crop. There was a sustained increase in kiwifruit acreage that extended through 1988. Total kiwifruit acreage peaked at 7,851 acres in 1988, and bearing acreage peaked at 7,330 acres in 1990. With low plantings and increased removals, bearing acreage decreased to 4,867 acres in 1997 and has since ranged from 4,500 to 4,875 acres (fig. 1). The 1997 Census shows that kiwifruit acreage was concentrated in the northern Sacramento Valley (Butte, Sutter and Yuba counties with 35.5% of total acreage) and in the southern San Joaquin Valley (Fresno, Tulare, Kern and Kings counties with 52.9% of total acreage). Tulare County (1,533 acres) and Butte County (1,475 acres) accounted for 51.4% of total California acreage.

As new kiwifruit acreage came into production in California and other areas around the world, average prices came down from their early highs. After acreage peaked in 1988, production reached a high of more than 52,000 tons in 1992 accompanied by record low average prices. The growers' response to low prices was to reduce new plantings, remove marginal acreage and investigate alternative methods for reducing unit costs of production and improving market returns. Severe price pressures in the early 1990s encouraged some growers to convert kiwifruit acreage to organic production. Kiwifruit culture in California lends itself organic production (Hasey et al. 1997). Typically, there are few insects or diseases that cause major problems, weeds are shaded from growing under mature full-canopied vineyards, and nutrient removal by the crop is minimal. Some of the most effective insecticides are also acceptable to regulators of organically grown produce. Since by law the organic transition and certification process requires 3 years, significant production of organic kiwifruit is a rather recent development.

Data on existing acreage and production of organic kiwifruit is scarce. To estimate organic kiwifruit acreage, we began with a directory of California Certified Organic Farmers (2001) to sort growers who listed kiwifruit as a crop grown. Some growers listed only kiwifruit while others listed multiple crops. We attempted to contact all growers of multiple organic crops to obtain a separate acreage estimate for kiwifruit. We also contacted each of the nine kiwifruit handlers known to be packing organic kiwifruit during the 2000-2001 crop year (October-September). Eight handlers provided us with estimates of their total pack and the acreage of organic kiwifruit operated by their growers. Using this procedure, we identified 20 organic kiwifruit producers with a total area of 290.5 acres. This appears to be almost all of the organic kiwifruit acreage — the California Department of Food and Agriculture (CDFA) reported 297 acres of registered organic kiwifruit in 2002, accounting for almost 6.5% of total California kiwifruit acreage.

Each handler was asked for their observations on acreage and production trends for California organic kiwifruit. Only one of the handlers who also produces kiwifruit reported that their own production would increase as their new plantings matured. None reported that they had nonbearing vines or acreage in transition to organic. One of the handlers reported being in contact with a grower who was converting 3 to 5 acres of kiwifruit to organic. Another handler reported that a neighboring ranch with 100 acres of kiwifruit was converting to organic production. Despite the stability reported for their own operations, all of the handlers expected production and sales of organic kiwifruit to increase in the future. This expected increase would come from higher yields as existing new organic plantings mature, from new plantings and conversions of conventional vineyards to organic, and from increased imports of organic kiwifruit. All of the handlers expressed the view that increased availability of organic kiwifruit will place downward pressure on prices.

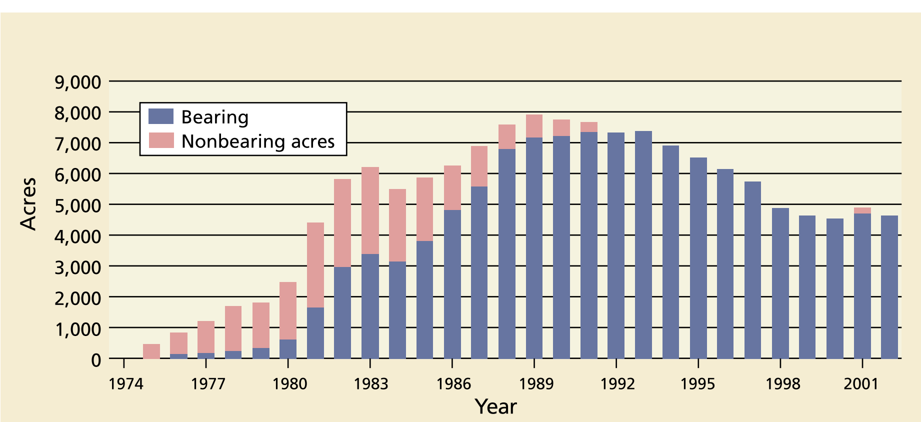


Fig. 1. California kiwifruit acreage, 1974–2001. Source: CASS 2002.

Import/export, consumption, prices

Kiwifruit imports and exports are a significant factor in seasonal marketing and pricing patterns. In addition to seasonality of supply and demand, several factors determine U.S. kiwifruit imports and exports. Three important trends are evident (fig. 2). First, total U.S. consumption of kiwifruit has increased significantly. Second, except for a pause from 1991 through 1994 when New Zealand exports were curtailed in an international trade dispute, the role of imports in total U.S. consumption has increased over time; kiwifruit imports have exceeded exports since 1985, and the United States continues to be a net importer of kiwifruit. Finally, U.S. exports of kiwifruit have decreased over time, due to lower production in California and increasing competition from New Zealand and Italy in international markets.

Total and per capita U.S. consumption of kiwifruit has grown substantially since 1985, when 33.4 million pounds (0.14 pounds per capita) were consumed. Total U.S. kiwifruit consumption grew almost fivefold by 2000, reaching 158.2 million pounds with per capita consumption at 0.57 pounds. Imports of 114.3 million pounds accounted for just over 72% of total 2000 consumption.

The CKC issues Kiwifruit Industry Shipment System (KISS) reports during the marketing year, including data on the total crop broken down by package and size of fruit (CKC 2001, 2002). Beginning with the 2000-2001 crop, the commission began issuing separate reports for the total crop and for the organic portion. These reports provide the first detailed estimates for California organic kiwifruit production and marketing practices. The KISS summary report for the 2000-2001 crop year reported a total estimated marketable crop of 7,493,293 tray-equivalents (7 pounds of kiwifruit), with 397,723 tray-equivalents of organic kiwifruit. Organic kiwifruit accounted for 5.3% of total 2000-2001 California kiwifruit production. Total 2001-2002 production decreased to 5,834,847 tray-equivalents, with 353,806 tray-equivalents of organic kiwifruit. With the smaller crop, the organic share of production increased slightly to almost 6.1% of production.

There is no data on the role of organic kiwifruit in exports and imports. Some organic handlers indicated that at one time, they exported organic kiwifruit to several markets, including Canada and Japan, but that they cannot compete with Italian production in European markets. Only two handlers reported organic exports during the 2000-2001 marketing year, and the volumes were less than 10% of each of their packs. Domestic organic kiwifruit has competition from organic imports, which is likely to increase given New Zealand's push to expand organic production and sales. California organic handlers complained of price pressure from increased New Zealand kiwifruit in the domestic market during November and December 2000.

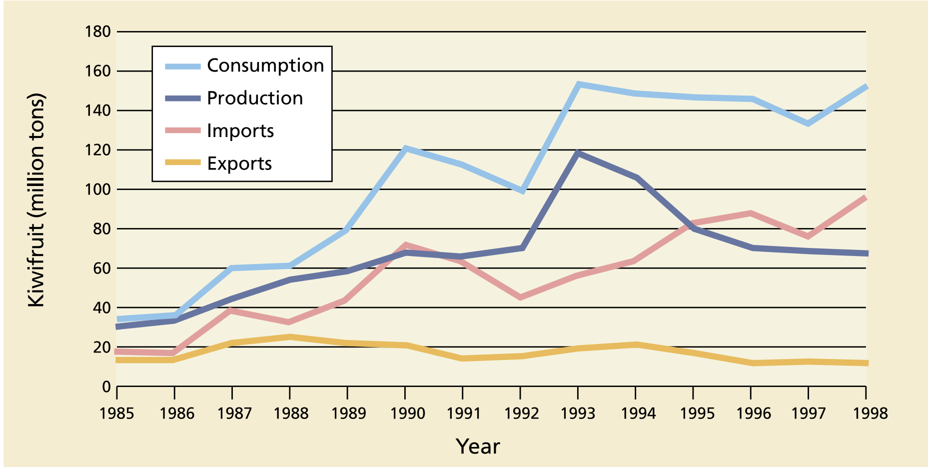


Fig. 2. U.S. kiwifruit: production, consumption, exports and imports, 1985–1998. Source: USDA 2002.

Reports from the U.S. Department of Agriculture (USDA) Foreign Agricultural Service (FAS) indicate that both Chile and New Zealand will be expanding production and exports of organic kiwifruit. FAS did not have estimates of the amount of organic kiwifruit produced in Chile, but did indicate that fresh organic kiwifruit production is expected to grow and that the target markets are the United States and Japan (USDA 1998). Zespri International, the marketing agency for New Zealand kiwifruit, has been encouraging New Zealand growers to convert to organic production. New Zealand produced almost 4,900 metric tons of organic kiwifruit in 1999 (about 2.5% of total production) and the organic share is projected to grow to 10% by 2005. Recently, New Zealand has exported more than half of its organic kiwifruit to Japan, with the remainder shipped to Europe and the United States. Prices for New Zealand organic kiwifruit sold in Europe, Japan and the United States have recently ranged from 8% to 15% above prices received for conventional fruit.

Organic kiwifruit has commanded a premium market price, although the premium has decreased over time as production and imports have increased. Organic kiwifruit handlers reported that there has been an organic premium

California Kiwifruit Commission

The standard measure for kiwifruit is a tray that holds 7 pounds of fruit. During the 2000-2001 growing season, 5.3% of the California kiwifruit crop was certified as organic, representing nearly 400,000 tray-equivalents of marketable fruit.

It takes about 8 years for kiwifruit vines to reach full production.

of 15% to 50%, depending on the style of pack, quality and time of the year. Single-layer flats of U.S. No. 1 grade fruit tend to have the highest prices per pound. An organic price premium of 20% to 30% was the value most often mentioned. Five of the eight handlers reported that organic kiwifruit prices tend to be more variable than prices for conventional kiwifruit. Two handlers reported that the differential between organic and conventional kiwifruit tends to increase as the season progresses and is greatest in February and March. Another handler reported that he tended to get the highest prices for organic kiwifruit early in the season. Despite the typical price premium, it is not unusual for organic kiwifruit to be sold as conventional kiwifruit for the conventional price. Five of the eight handlers reported that, on occasion, they had sold organic kiwifruit for the same price as conventional. This may be due to the seasonal price variability mentioned or, in some cases, to market channel requirements.

Kiwifruit marketing patterns

Kiwifruit is picked firm and unripe, and placed in refrigerated storage. It then ripens within a few days of being taken out of storage. While California kiwifruit can be harvested in September, most is picked from mid-October through the end of November. The fruit must mature on the vine and reach a minimum soluble solids requirement of 6.2% to 6.5% before being harvested to achieve ideal sweetness when ripe. Kiwifruit that remains on the vine longer and reaches a higher soluble solids level will taste sweeter when ripe and also tends to store better, making it easier to handle and more appealing to consumers. California kiwifruit is typically marketed during the 8-month period from October through May. There is usually competition with Southern Hemisphere imports during April, May, October and November when the marketing seasons overlap. There are important differences in marketing organic and conventional kiwifruit.

Marketing channels. Organic handlers were asked to whom they sold their organic kiwifruit and if their mix of customers differed from that of conventional kiwifruit handlers. One organic handler also packs a large volume of conventional fruit, others formerly packed conventional fruit, and all are in close contact with conventional handlers. While organic kiwifruit is sold to many of the same customers as conventional kiwifruit (such as large chains, specialty stores and institutional buyers), there are some important differences. The largest volume of organic kiwifruit is sold to organic wholesalers and distributors who service the retailers who stock organic products. Some handlers have established relationships with small and midsized chains that tend to specialize in organic foods, such as Whole Foods or Wild Oats. One handler said, "Organic customers differ from conventional customers in that they order smaller quantities and often use a common distributor or buying office, which provides the mix of organic produce that their individual stores require." Another commented, "The natural food and traditional food stores that buy organic kiwifruit expect better quality." Three of the handlers said that they had, on occasion, sold organic kiwifruit to large chain buyers, but none listed large national chains as their primary outlet.

Shipping containers. Common shipping containers for kiwifruit include single-layer trays, three-layer cartons, cartons with twenty 1-pound film bags, 22-pound volume-fill cartons, 125-pound bulk bins and other containers. The single-layer tray is the premium package, accounting for just 2.65% of the 2001-2002 crop. This is a significant change from several years ago. In 1987-1988, for example, over 80% of the crop was packed in single-layer trays and only about 8% was packed in volume-fill cartons. Volume-fill cartons, with 85% of the estimated 2001-2002 total crop, are currently the most popular container. This changeover in shipping containers is in part due to the difference in packing and container costs, with the cost for volume-fill being about 40% of that for single-layer trays. Also, the increase in consumption has increased demand for containers holding more fruit.

There is a significant difference in the containers used to pack conventional and organic kiwifruit. Overall, volume-fill cartons are the most popular container but their use varies. Conventional kiwifruit handlers have recently packed 82% of their pack in volume-fill cartons but the comparable proportion for organic handlers was just over 44%. Organic kiwifruit handlers tend to have more variety in their packaging, with just over 16% in single-layer trays, another 17% in 1-pound film bags, and 16% in 125-pound bins. The distribution

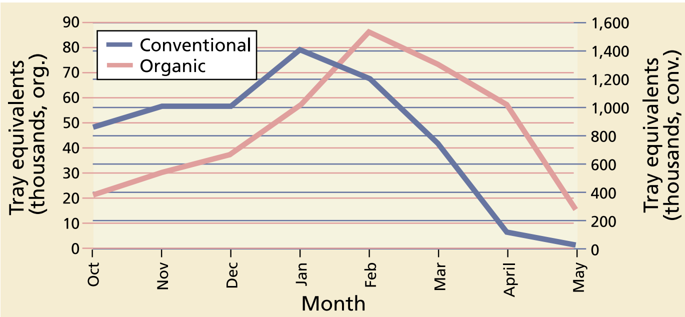


Fig. 3. Average monthly sales for California organic and conventional kiwifruit, 2000-2001 and 2001-2002 crop years. Source: CKC 2001, 2002.

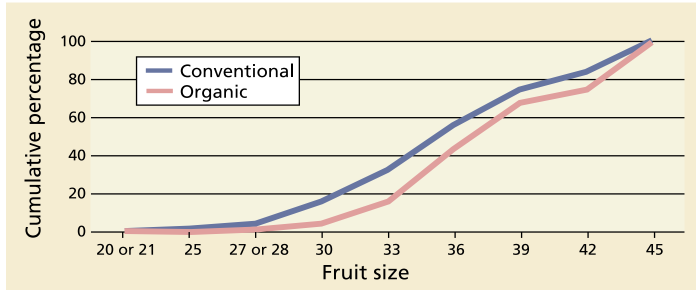


Fig. 4. Cumulative distribution of organic and conventional kiwifruit by size, California average of 2000-2001 and 2001-2002 crop years. Size refers to the number of kiwifruit required to fill a standard single-layer tray weighing 7 pounds. Source: CKC 2001, 2002.

of package types for organic kiwifruit is based on the more specialized nature of their market and the existence of premium prices for the organic product.

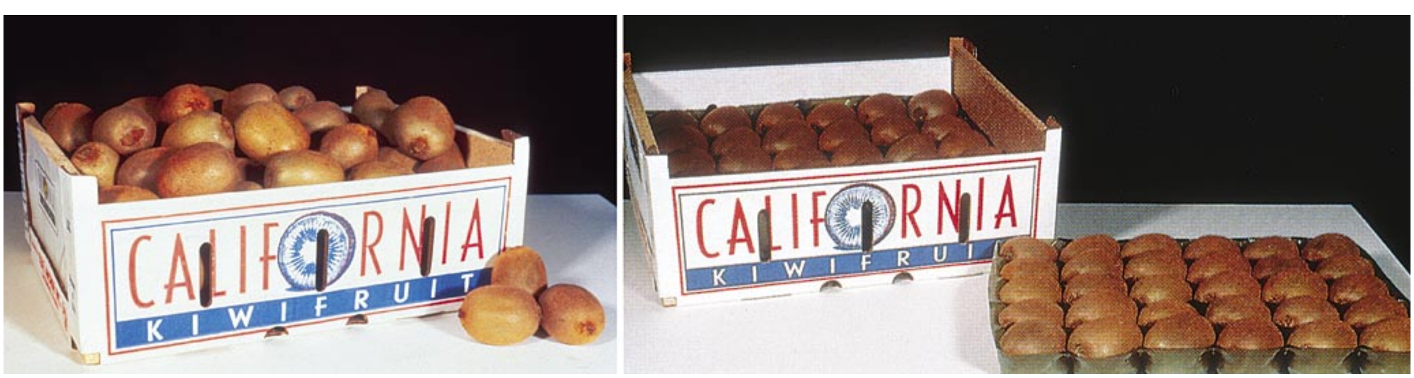
Seasonal shipment patterns. The California kiwifruit harvest begins in September, with significant shipments to retail markets beginning in early October. Sales typically begin slowly during October and November because of the presence of competing fruit from Chile and New Zealand. Sales build through December, typically peak in January, remain high during February and March and then decrease significantly in April and May. While imports are typically present throughout the year, significant shipments from the new crop in the Southern Hemisphere begin to arrive in April and May. There may be small shipments of domestic kiwifruit in June, July and August, but an abundance of new crop imports significantly weakens the price for old crop fruit. The actual pattern of shipments varies from year to year as a result of crop size, the pattern and volume of imports, and price trends.

Average monthly shipments of organic and conventional kiwifruit for California's 2000-2001 and 2001-2002 crop years show that the organic crop tends to be shipped later in the marketing year than shipments of conventional kiwifruit (fig. 3). The majority of conventional kiwifruit was shipped during the first 4 months of the season, while the majority of organic kiwifruit was shipped during the last 4 months. This is consistent with industry participants' descriptions of previous marketing patterns. An observed tendency to market organic kiwifruit later in the year was attributed to (1) less competition for organic fruit at the end of the marketing season because there has not been much imported organic fruit, and (2) the ability to store organic kiwifruit. For the 2000-2001 crop year, a portion of this difference in marketing conventional and organic fruit may have been due to market conditions during the first 3 months of the marketing season. In our discussions with organic kiwifruit handlers during November and December, each expressed concern about the large amounts of New Zealand kiwifruit still in the market and the effects of late imports on prices. Based on the shipment data, it appears that organic handlers delayed sales more than conventional handlers did, while waiting for market conditions to improve.

Fruit-size distribution. The fairness of the federal marketing order's minimum-grade and size requirements is sometimes questioned, particularly when cultural methods and production conditions may impact the shape and size distribution of fruit. An important question for this study is, "Do minimum grade and size standards have an equal impact on organic and conventional kiwifruit?" To provide a partial answer we can compare the size distribution of organic and conventional kiwifruit for the most recent crop. We have no data on the amount of kiwifruit that is culled for not meeting grade and size standards.

For comparative purposes, fruit size refers to the number of kiwifruit required to fill a standard single-layer tray weighing 7 pounds (fig. 4). For example, size 25 refers to 25 fruit to a tray and size 45 to 45 fruit to a tray. Size 20 or 21 is the largest fruit and 45 the smallest. The minimum weight of a tray has been 7 pounds, which is the conversion factor used by the industry to calculate the volume of kiwifruit in tray-equivalents (TE). Careful comparisons of the percentage size distributions show that for

California Kiwifruit Commission



Kiwifruit is packed into several different kinds of containers.

California Kiwifruit Commission

In a survey, California organic kiwifruit growers noted that their customers increasingly want high-quality fruit.

the most recent crop year, conventional kiwifruit tended to be larger on average than organic kiwifruit. Looking at cumulative percentages for 2000-2001, only 2.8% of organic kiwifruit was size 30 or larger, while 12.86% of conventional kiwifruit was size 30 or larger. At the other end of the scale, the proportion of kiwifruit size 39 and smaller was 52.26% and 40.96%, respectively, for organic and conventional kiwifruit. In 2001-2002, 5.8% of organic kiwifruit was size 30 or larger, while 19.0% of conventional kiwifruit was size 30 or larger. At the other end of the scale, the proportion of kiwifruit size 39 and smaller was 60.4% and 48.0% respectively, for organic and conventional kiwifruit. The smaller average size for organic kiwifruit that is evident for both years is consistent with "conventional wisdom" in the industry.

Views on marketing issues

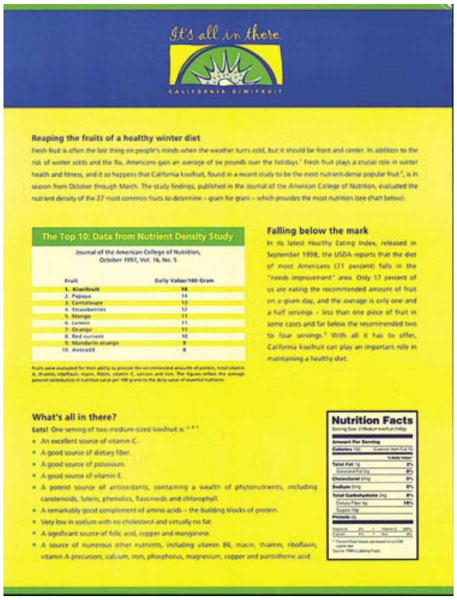
The main activity of the federal marketing order is to regulate and enforce mandatory minimum quality standards for grade, size and maturity. Organic and conventional kiwifruit must satisfy the same standards to be marketed. Organic kiwifruit has a smaller size distribution than conventional kiwifruit, which could pose grading problems for organic handlers and producers.

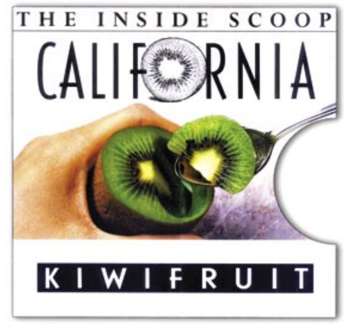
Handlers, as might be expected, expressed a variety of opinions on the value of minimum quality standards for organic kiwifruit. Two of the smallest producer-handlers, who market only their own fruit, said that the minimum size requirement tended to result in more culls for organic than conventional fruit. One, however, added that the economic impact was minimal because organic consumers would not buy the small cull fruit. Four of the eight handlers were very positive and supportive of the existing quality standards for kiwifruit. They stated that the quality standards help them sell their organic kiwifruit by maintaining consistent quality and by giving buyers confidence in the product. Each of the four also believed that the current standards are fair. One handler criticized the maturity standard for having sugar levels that are too low (the average minimum maturity of 6.5% soluble solids was reduced to 6.2% for the 2000-2001 season).

The organic kiwifruit handlers who we interviewed are concerned about the quality of their pack. One handler described the market evolution for organic kiwifruit as beginning with customers who were most concerned about farming practices. As consumers became acquainted with organic kiwifruit, they came to appreciate the taste but were not too concerned with appearance. Now, customers want fruit that not only tastes good but also is free of blemishes. Another handler commented that, "given a choice, customers prefer and are willing to pay for less cosmetically challenged fruit." Several handlers indicated that organic consumers are a quality-conscious and premium market segment that demands higher quality than conventional buyers. Statements such as "my consumers set the standards, which are above the minimum standards," are common. One handler markets only his U.S. No. 1 organic kiwifruit as organic; the kiwifruit that does not meet the No.1 grade standard are sold as conventional kiwifruit.

Handlers were asked if the CKC advertising and promotion programs help them market organic kiwifruit and if they do any advertising on their own. All but one of the handlers said that the present CKC advertising and promotion program does not help market organic kiwifruit. One handler commented that past CKC advertising and promotion had helped market both organic and conventional kiwifruit, but with smaller budgets and reduced efforts the present impact is small. He also commented that the commission does a good job with a limited budget. Another commented that the commission advertising and promotion programs are oriented to conventional kiwifruit, do not help market organic kiwifruit and are a waste of time and money. Four of the eight handlers spend a moderate amount of advertising dollars for their organic kiwifruit. All of the expenditures are in industry publications (such as the organic directory, "The Packer") directed toward the trade to inform wholesalers and other buyers about the availability of organic kiwifruit. None of the handlers do any consumer advertising.

Organic kiwifruit handlers offered a number of suggestions regarding marketing order and CKC programs that they believe would help market organic kiwifruit. Regarding grades and standards, handlers proposed higher minimum sugar levels and a separate set of standards for organic fruit. One handler was concerned that California kiwifruit





The California Kiwifruit Commission, established in 1980 to conduct research and promote kiwifruit, produces and distributes marketing materials for kiwifruit, although none are specific to organic products.

is at a disadvantage to imports because the USDA does not enforce mandatory minimum quality standards for foreign suppliers. Most suggestions involved advertising and promotion. Handlers would like to have CKC programs specific to organic kiwifruit, such as point-of-purchase materials, a page on the CKC Web site, a specially designed PLU (price lookup) sticker, and separate advertising and promotion on the attributes of organic kiwifruit.

Marketing organic fruits and nuts

Based on discussions with handlers, it is possible to draw some tentative conclusions about marketing organic fruit and nuts. First, there is a finite set of consumers who are willing to pay a premium price for organic products, and as available supply approaches the quantity demanded by these consumers, there will be increased downward pressure on the organic premium. Most of the organic handlers contacted in this study expect organic production to continue to increase and the difference between the price of organic and conventional product to decrease. Some organic product is already being sold as conventional product and the amount will increase as organic production and the availability of organic imports increases.

Second, the quality expectations of organic consumers are changing and there is less willingness to accept cosmetic defects on organic fruit. This trend will place even more pressure on overall returns for organically produced crops. Third, organic crops will continue to be niche products with more middlemen and more specialized channels of distribution than is typical for conventional fruits and nuts. Finally, while successful industry advertising and promotion programs may improve prices for conventional products and provide a higher floor price for organic products, conventional advertising and promotion typically provide little information on the unique features that organic producers attribute to their products. Organic producers face a significant challenge in building the demand for their products to maintain price differentials as production increases.

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COMINGUP

Commercial fisherman James Gullett (left), of Trinidad, pulls in a Dungeness crab trap off the Humboldt County coast for a Sea Grant tagging project, with the assistance of Humboldt State University student Aaron Bliesner.

Maintaining a sustainable crab fishery

Dungeness crab support one of the most valuable commercial fisheries in California, yet in recent decades the fishery has intensified significantly, with most of the crab landed during the first 6 weeks of the 7-month season. While current regulations — including seasons, size limits and protection of female crab — appear to ensure sustainability of crab populations, alternative approaches could increase the net economic benefit from the fishery. In an upcoming issue of *California Agriculture,* UC scientists survey fishermen's operating costs and their opinions on 13 potential alternative management measures, ranging from trap limits to quotas. The authors explore the feasibility of various policy options to improve the economic performance of Dungeness crab fisheries in California.

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