OCTOBER-DECEMBER 2007 • VOLUME 61 NUMBER 4

California Agriculture

Confronting a scarcity of clean and abundant water

Also:
Managing *E. coli*
Crop marketing

University of California | Peer-reviewed Research and News in Agricultural, Natural and Human Resources

Sustainable food systems link growers to new consumer markets in California

Gail Feenstra
Food Systems Analyst,
UC Sustainable
Agriculture Research and
Education Program

Tom Tomich
Director,
Agricultural Sustainability
Institute, UC Davis

IN the last decade, Californians at every step of the food chain have pioneered new, sustainable systems of cultivation, marketing and distribution that promise to be more economically viable, environmentally sound and socially just. Four crises have driven these changes: (1) an epidemic rise in obesity, now a leading cause of preventable death; (2) a need for social justice in the food system, including reforms of working conditions, adequate wages for farm and factory workers, and food security for inner-city residents; (3) a depletion of our natural resources, particularly water, on which California depends for many crops; (4) increasing signs of global warming, high carbon emissions and unsustainable energy expenditures for food production. We currently use 10 kilocalories (kcals) of fossil fuel to produce 1 kcal of food energy.

In addition, industrialization, globalization and economic concentration in the food and agricultural system have made it difficult for family farmers, especially mid-scale growers, to remain in business, and for consumers to access healthful, sustainably produced foods from their local areas.

Since 1990, the UC Division of Agriculture and Natural Resource's (ANR) Sustainable Agriculture Research and Education Program (SAREP) has addressed these concerns by granting funds for dozens of food systems projects throughout the state (http://sarep.ucdavis.edu). Researchers have examined farmers' markets in low-income communities (see page 149), regional marketing organizations, regional processing facilities, food policy councils, year-round employment for agricultural workers, and urban gardening programs.

The new Agricultural Sustainability Institute (ASI) at UC Davis has now become the hub for a wide variety of campus programs that have advanced sustainable food systems for the last 20 years, including the Student Farm, the Sustainable Agriculture Farming Systems (SAFS) Project and the Long-term Research on Agricultural Systems (LTRAS) Project (see page 149). ASI has also been delegated with the responsibility for managing ANR's systemwide SAREP program.

SAREP and ASI have embarked on two new participatory research and extension projects; both will help satisfy a growing demand for foods that leave a smaller "carbon footprint," while simultaneously providing new markets for regional growers. The first project partners SAREP with the UC Santa Cruz Agroecology and Sustainable Food Systems Program (see page 152), the UC Davis Department of Agricultural and Resource Economics and the nonprofit Community Alliance with Family Farmers to research new farm-to-institution (specifically colleges and universities) markets for regional growers (see page 154). Institutional vendors are the second largest sector of the U.S. food-service market, spending $30.9 billion for food at schools and colleges and another $42.8 billion in 2006 at institutions such as hospitals, corporate cafeterias and airlines. In California alone, there are approximately 21,000 educational and health care institutions that provide meals to consumers daily, yet little is understood about this emerging market.

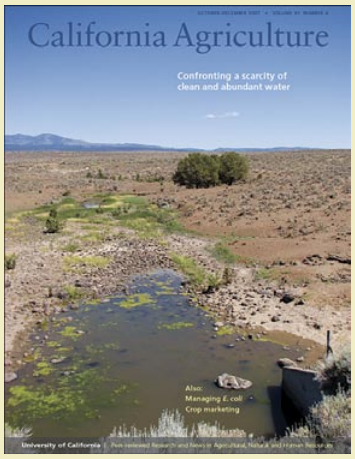
To date, the study team has conducted surveys that explore the extent to which new distribution infrastructures are able to supply an increasing demand for local, organic and sustainable food products, and what needs to be done to "ramp up" the system successfully. At an outreach event in July 2007, more than 100 growers, buyers, researchers and policymakers shared information and preliminary research results, and created new business opportunities. We expect the results will be used to strengthen this expanding initiative.

The second project is a partnership between ASI, SAREP, the Bon Appetit Management Company Foundation, the UC Davis Institute of Transportation Studies and several UC Davis departments. This project will analyze foods and provide recommendations for a "low-carbon diet," by gathering data on the embedded energy and carbon emissions associated with a variety of foods. The project will use a methodology called "life-cycle analysis," which includes energy inputs/emissions from farm to retail. In October 2007, an international symposium at UC Davis will gather input from European and national experts as well as UC researchers for a white paper and to form the framework of a collaborative research agenda.

These two initiatives, although in their early stages, are already revealing some key insights. First, sustainable food systems are complex and dynamic. It takes a multidisciplinary research and outreach effort to address the challenges and opportunities that arise. Second, partnerships among institutions of higher education, industry and nonprofit community groups ensure that the research is relevant and timely. Third, ongoing and new communication systems are important to increase the likelihood of cooperation between related food systems and to avoid redundancy.

To that end, the Agricultural Sustainability Institute has embarked on a strategic planning process that involves input from food and agricultural systems stakeholders across many levels. We invite participants to help us prioritize issues and embark on new research and outreach efforts. *To engage in this process, please visit: http://asi.ucdavis.edu/strategicplanning.htm.*

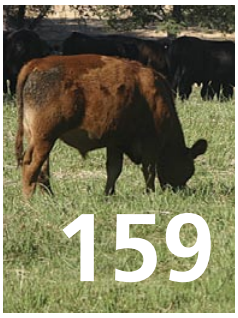
TABLE OF CONTENTS

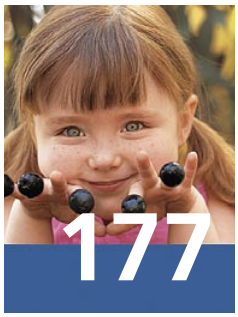


Cover: **Water quantity and quality will continue to be critical issues facing California (see pages 156–171), such as in the arid Klamath River Basin. *Photo by Missy Merrill-Davies.***

News departments

Research and reviews





Nutrition article wins extension award

The National Extension Association of Family & Consumer Sciences has chosen "Food behavior checklist effectively evaluates nutrition education," published in the January-March 2006 issue of *California Agriculture* (Vol. 60, No. 1), as the Western Region Winner for its Program Excellence Through Research Award. The authors are Mary L. Blackburn, Marilyn S. Townsend, Lucia L. Kaiser, Anna C. Martin, Estella A. West, Barbara Turner and Amy B. Joy. The award was presented at the NEAFCS Annual Session and Exhibits in St. Paul in September.

Correction: There was a typographical error in "New late-season navel orange varieties evaluated for quality characteristics," by Kahn et al. (July-September 2007; Vol. 61, No. 3, p. 138): Valencia oranges are not navel oranges. *California Agriculture* regrets the error.

About California Agriculture

California Agriculture is a quarterly, peer-reviewed journal reporting research, reviews and news from the Division of Agriculture and Natural Resources (ANR) of the University of California. The first issue was published in December 1946, making it one of the oldest, continuously published, land-grant university research journals in the country. The circulation is currently about 15,000 domestic and 1,800 international.

Mission and audience. *California Agriculture*'s mission is to publish scientifically sound research in a form that is accessible to a well-educated audience. In the last readership survey, 33% worked in agriculture, 31% were faculty members at universities or research scientists, and 19% worked in government agencies or were elected office holders.

Current indexing. *California Agriculture* is indexed in the Commonwealth Agricultural Bureau databases, Proquest, AGRICOLA and Google Scholar. In addition, all peer-reviewed articles are posted at the California Digital Library's eScholarship Repository.

Authors. Authors are primarily but not exclusively from ANR; in 2005 and 2006, 14% and 34% (respectively) were based at other UC campuses, or other universities and research institutions.

Reviewers. In 2005 and 2006, 13% and 21% (respectively) of reviewers came from universities and research institutions or agencies outside ANR.

Rejection rate. Our rejection rate is currently 26%. In addition, in two recent years the Associate Editors sent back 11% and 26% for complete resubmission prior to peer review.

Peer-review policies. All manuscripts submitted for publication in *California Agriculture* undergo double-blind, anonymous peer review. Each submission is forwarded to the appropriate Associate Editor for evaluation, who then nominates three qualified reviewers. If the first two reviews are affirmative, the article is accepted. If one is negative, the manuscript is sent to a third reviewer. The reviewers and Associate Editors almost always require revision before acceptance. The Associate Editor makes the final decision, in consultation with the Managing and Executive Editors.

Editing. After peer review and acceptance, all manuscripts are extensively edited by the *California Agriculture* staff to ensure readability for an audience of lay readers and multidisciplinary academics.

Submissions. *California Agriculture* manages the peer review of manuscripts online. Please read our Writing Guidelines *before* submitting an article; go to http://californiaagriculture.ucop.edu/submissions.html for more information.

Letters. The editorial staff welcomes your letters, comments and suggestions. Please write to us at: 6701 San Pablo Ave., 2nd floor, Oakland, CA 94608, or calag@ucop.edu. Include your full name and address. Letters may be edited for space and clarity.

Subscriptions. Subscriptions are free within the United States, and $24 per year outside the United States. Single copies are $5 each. Go to http://californiaagriculture.ucop.edu/resub.html or write to us. Orders must include payment by check or international money order in U.S. funds, payable to UC Regents. MasterCard/Visa accepted; include complete address, signature and expiration date.

Republication. Articles may be reprinted, provided no advertisement for a commercial product is implied or imprinted. Please credit *California Agriculture*, University of California, citing volume and number, or complete date of issue, followed by inclusive page numbers. Indicate ©[[year]] The Regents of the University of California. Photographs in print or online may not be reprinted without permission.

California Agriculture

Peer-reviewed research and news published by the Division of Agriculture and Natural Resources, University of California

VOLUME 61, NUMBER 4

6701 San Pablo Ave., 2nd floor, Oakland, CA 94608
Phone: (510) 642-2431; Fax: (510) 643-5470; calag@ucop.edu
http://CaliforniaAgriculture.ucop.edu

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 address above.

Farmers' markets benefit growers, local economies

Direct-marketing venues such as farmers' markets help farmers sell their products in local communities for higher prices than they could get from wholesalers, according to a UC food systems analyst who reviewed studies of the markets and their growth.

Social interaction is an important benefit of farmers' markets.

"Farmers benefit from the ability to sell smaller and variable quantities, and learn the skills they need to increase their business," says Gail Feenstra of the UC Sustainable Agriculture Research and Education Program (SAREP). Her article appeared in the January 2007 "Food for Thought" issue of the Italian journal *Gastronomic Sciences*.

In 1970 there were 340 farmers' markets in the United States; by 2006, there were more than 4,385 farmers' markets, Feenstra says. California has almost 500 markets, half of which are open year-round.

Farmers, communities and individual residents are the main beneficiaries of local farmers' markets, Feenstra says.

The total gross receipts that farmers receive at farmers' markets, although modest by comparison to supermarkets, are still significant. Her 1999 study of California farmers' markets estimated total annual sales at approximately $140 million.

Likewise, "the social benefit that farmers' markets bring to communities can't be overestimated," Feenstra says. In her interviews with market patrons, she found them to be a major source of interaction, both between farmers and their customers, and among market visitors.

Low-income and elderly community residents receive particular benefits from farmers' markets, Feenstra says, where healthful, affordable, nutritious food or ethnically appropriate foods are more likely to be available than at retail food outlets.

For more information: http://www.unisgjournal.it/index_eng.htm.

IPM pub focuses on light brown apple moth

Aircraft sprayed pheromones in parts of Monterey County in early September and are now targeting Santa Cruz in an effort to disrupt mating and eradicate a ravenous new exotic pest, the light brown apple moth. An aggressive 11-county program is targeting the dime-sized moth from Australia, *Epiphyas postvittana,* which attacks more than 250 plant species.

UC Statewide Integrated Pest Management Program has produced a new publication to answer questions about moth identification, its biology, and management alternatives and regulation. The free online guide was produced by about 10 scientists from the United States and two other countries.

Since the first detection on Feb. 27 in Berkeley (Alameda County) trappers have captured more than 7,700 specimens in 11 counties (through Sept. 14), according to Kevin Hoffman, primary state entomologist with the California Department of Food and Agriculture (CDFA). Counties affected are Alameda, Contra Costa, Los Angeles, Marin, Monterey, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz and Solano. (The moth previously invaded New Zealand, the United Kingdom, Ireland and Hawaii.)

The U.S. Department of Agriculture (USDA) announced Aug. 10 an infusion of $15 million in federal funding to fight the infestation. This allows the Cooperative Light Brown Apple Moth Eradication Project to move forward to protect the environment and prevent the spread of the moth elsewhere in the United States.

Photos courtesy of David Williams, Perennial Horticulture, Victoria, Australia

***Top,* larva of the light brown apple moth; *bottom left,* the female, and *right,* male moths. Adults are about three-quarter-inch long.**

The pest damages a wide variety of crops, including grapes, citrus and stone fruits (peaches, plums, nectarines, cherries, apricots), as well as common landscape trees such as cypress, redwoods and oaks and numerous other varieties found in urban-suburban landscaping and the natural environment.

Nursery products are especially vulnerable because many are shipped outside the affected counties to other states and internationally. The USDA Animal and Plant Health Inspection Service and CDFA have implemented interstate and intrastate quarantines.

To download a free copy of "Light Brown Apple Moth: Quarantine, Management, and Potential Impacts," go to: http://www.ipm.ucdavis.edu/EXOTIC/lightbrownapplemoth.html.


Jack Kelly Clark


Kathy Keatley Garvey

Left, **the Mediterranean fruit fly is smaller than a housefly.** ***Right,*** **In mid-September, CDFA began aerial releases of millions of sterile male Medflies in and around Dixon.**

Medfly outbreak in Dixon

Agricultural officials are taking action against a Mediterranean fruit fly infestation detected within the city limits of Dixon in northern Solano County. Within a 5-day period from Sept. 10 to 14, officials found 12 adult Medflies at five sites, and 33 larvae in a single peach tree in a back yard.

"It's definitely breeding, but it's all within the city of Dixon so far," says Kevin Hoffman, primary state entomologist with the California Department of Food and Agriculture (CDFA). "We want to keep them from infesting the commercial crops."

This is the first time that Medfly has been discovered in Solano County and the second time in the 400-mile Central Valley. Dixon is about 20 miles southwest of Sacramento.

Smaller than a housefly, the Medfly is considered one of the world's worst agricultural insect pests due to its wide distribution, wide range of hosts and ability to tolerate cool climates. Its larvae infest more than 260 fruits, vegetables and nuts. First detected in California in 1975, Medfly particularly threatens thin-skinned fruits such as peach, nectarine, apricot, avocado, grapefruit, orange and cherry. According to CDFA Secretary A.G. Kawamura, its permanent presence in California could result in annual losses of $1.3 billion to $1.8 billion.

The CDFA Medfly Action Plan kicked into high gear immediately following the initial find, Hoffman says. The action plan includes: stripping all fruit from trees within a 100-meter radius of all Medfly finds; ground-spraying the organic compound Naturalyte (the active ingredient is spinosad, a naturally occurring product of a soil bacteria) within a 200-meter radius; setting 1,700 fruit fly traps within an 81-square-mile grid in all of Dixon and the surrounding area; and aerially releasing 1.5 million sterile male Medflies (dyed pink for easy detection) on Sept. 14 over a 12-square-mile area, with weekly releases of 3 million sterile Medflies for at least 9 months. CDFA also established a 114-square-mile quarantine area, and the command center at the Dixon May Fair grounds will be in operation for at least a year.

Unlike earlier Medfly infestations in California (the seven-county Bay Area infestation in 1980, and the 1989–90 and 1993–94 infestations in Southern California), which involved aerial spraying of the controversial insecticide malathion, the Dixon infestation deploys spinosad.

"Spraying of the spinosad bait is a safe approach," UC Davis entomologist Frank Zalom says. "It has been used successfully by our growers to treat olive fruit flies, and it has been used successfully in Hawaii to suppress there."

Likewise, releasing sterile male flies "has a proven track record in Southern California of breeding with wild females to help achieve eradication," says Steve Lyle, director of CDFA's Office of Public Affairs. "The females breed once and if they breed with a sterile male that ends their reproductive activities."

To report infested fruit, call CDFA at (800) 491-1899, or go to: www.cdfa.ca.gov. For more information, go to: http://entomology.ucdavis.edu/news/medfly infestation.html.

Flies could transmit exotic Newcastle disease between poultry

Laboratory testing shows that flies exposed to a food source infected with exotic Newcastle disease (END) can pick up the virus and carry it for several days, perhaps later passing it on to chickens that eat the food.

"Flies can carry END virus and evidence is mounting that flies may be able to transmit the virus between chickens," says Alec Gerry, UC Riverside assistant veterinary entomologist.

END is a contagious and fatal viral disease affecting the respiratory, nervous and digestive systems of poultry and other birds. "END is so infectious that many birds die without ever showing signs of illness," Gerry says.

In 2002 and 2003, an END outbreak in California resulted in the quarantine of nearly 20,000 buildings, the destruction of 3.2 million birds, and eradication efforts that cost $170 million.

UC Riverside postdoctoral associate Seemanti Chakrabarti found that flies (bronze blow fly, housefly and little house fly) routinely contract infectious END virus at locations where chickens are also infected. Presumably, flies are making contact with the virus when they land or feed on poultry manure containing the virus.

"Conservatively, flies should be considered as transmitters of the END virus," Gerry says. "This means that fly control should be an important part of a biosecurity program at all poultry operations."

More flavonoids in organic tomatoes, study shows

Tomatoes grown organically at the UC Davis Long-Term Research on Agricultural Systems project (LTRAS) had significantly higher levels of two important antioxidants, according to a study in the June 2007 *Journal of Agriculture and Food Chemistry*.

"The is the first time that a study has shown well-quantified changes in tomato nutrients over a period of years in organic farming systems," says lead author Alyson E. Mitchell of the Department of Food Science and Technology and Department of Plant Sciences at UC Davis.

Dried tomato samples were collected between 1994 and 2004 from LTRAS plots, a 100-year project that began in 1993 to compare organic, sustainable and conventional practices. The organic tomatoes had significantly higher ($P < 0.05$) levels of the flavonoids quercetin and kaempferol; the 10-year mean levels were 79% and 97% higher, respectively, than those in conventionally grown tomatoes.

Fruits and vegetables are a primary source of flavonoids and other antioxidants in the diet. Epidemiological studies suggest that they may protect people who eat more produce against cardiovascular disease and, to a lesser extent, against cancer and age-related diseases such as dementia.

In this study, the levels of flavonoids increased over time in samples from organic treatments, whereas flavonoids did not vary significantly in conventional treatments. "This increase corresponds not only with increasing amounts of soil organic matter accumulating in the organic plots but also with reduced manure application rates once soils in the organic systems had reached equilibrium levels of organic matter," Mitchell and co-authors wrote.

The authors theorized that over time, plants grown in organically managed soils — those treated with compost, manure and cover crops, rather than synthetic fertilizers — can devote more energy to producing flavonoids and may be less susceptible to pest pressures.

For more information: http://mitchell.ucdavis.edu.

John Stumbos/UC Davis

Alyson Mitchell (right) and graduate student Joy Rickman examine dried tomatoes at the UC Davis food science lab.

Frog-killing fungus may be spread by reproduction

A deadly fungus that has decimated populations of mountain yellow-legged frogs in the Sierra Nevada can likely be spread by sexual reproduction, seriously complicating efforts to save the frogs from extinction, according to a new genetic analysis by UC Berkeley researchers.

The dramatic decline of the mountain yellow-legged frog over the past several decades has been attributed to the introduction of nonnative predatory fish in some areas and to chytridiomycosis, a quickly spreading disease caused by a waterborne fungus, *Batrachochytrium dendrobatidis*.

The study, which appeared in *Proceedings of the National Academy of Sciences* in August, suggests that the frog-killing fungus may end up playing the bigger role in the frog's demise because of the pathogen's ability to spread over long distances and possibly persist in the environment as a consequence of sexual reproduction.

"This group of fungi, when it reproduces sexually, can create spores that can last for a decade," says John Taylor, UC Berkeley professor of plant and microbial biology. "That could make this pathogen a harder problem to defeat. As a resistant spore, the fungus could be transported by animals, including humans or birds, or lay dormant in an infected area until a new host comes along."

In the western United States, the fungus has been spreading quickly, moving west to east across the Sierra Nevada at a pace of about a mile per year, according to the researchers. Tens of thousands of mountain yellow-legged frogs in hundreds of sites have virtually disappeared in the wake of the pathogen's emergence in the area.

Vance T. Vredenburg

Healthy mountain yellow-legged frogs at Kings Canyon National Park.

Science briefs *are compiled from news reports.*

Breaking new ground: 40 years

UC Santa Cruz celebrates sustainable innovation in farming, food systems

CASFS/UC Santa Cruz

Researchers working at the UC Santa Cruz farm (shown) and Alan Chadwick Garden helped to pioneer organic and sustainable growing methods. The Center for Agroecology and Sustainable Food Systems (CASFS) celebrated the garden's 40th anniversary this summer.

In 1967, a charismatic English gardener — also an accomplished Shakespearean actor, painter, violinist and athlete — journeyed to California to establish an organic garden. On a steep hillside at UC Santa Cruz, Alan Chadwick broke ground for a student garden designed to demonstrate the biodynamic methods he had learned from his childhood tutor, Rudolf Steiner. Although he left after 5 years to establish similar projects elsewhere, Chadwick's innovative project took root. Today more than 1,200 graduates of the UC Santa Cruz farm and Garden apprenticeship program are often credited with pioneering what is now the mainstream, fast-growing organic food movement.

Alan Chadwick circa 1967

In 1980 the Agroecology Program was established within the UC Santa Cruz Division of Social Sciences to integrate the apprenticeship's hands-on focus with academic research; in 1994 the program's name was changed to the Center for Agroecology and Sustainable Food Systems at UC Santa Cruz (CASFS). CASFS focuses on ecological sustainability and social justice in food and agricultural systems; much of its research is in social sciences.

This year UC Santa Cruz celebrates the 40th anniversary of the Alan Chadwick Garden. In July, the "Back Forty: Breaking New Ground" conference provided hundreds of participants, many of them former apprentices, with tours of the Chadwick Garden, the 25-acre organic UC Santa Cruz farm, and local organic farms started by graduates; culinary celebrations with reflections on the early days at the Chadwick Garden, including a midsummer night's dinner in the apple orchard attended by nearly 600 people; and a symposium that featured graduates' innovative projects across the country and in Africa, and an overview of CASFS research.

In symposium remarks, graduate Brian McElroy, organic business manager at Driscoll's Strawberry Associates, quoted a recent survey by the Perishables Group (fresh-food industry consultants) noting that 75% of Americans are now buying organic produce, at least on occasion. "The movement is still gaining momentum," he said. "A quarter of Americans have started buying organic just in the last 12 months."

Driscoll's, the world's largest shipper and packer of berries, "aims to be 15% organic by 2011," McElroy said. Achieving that volume of organic berries from its growers depends in part on CASFS, he said. "We need the research to show whether something works or not."

One-two punch at Lygus

The symposium highlighted organic agricultural research, which often involves collaborations among growers, UC Santa Cruz and other faculty, and UC Cooperative Extension farm advisors.

UC Santa Cruz entomologist Sean L. Swezey has developed methods to limit lygus bug damage in organically managed strawberry crops. "Lygus bugs are a real problem, because they're native and they feed on a wide variety of flowering plants," Swezey says. "In the strawberry field, they feed on developing berries and cause gnarled, cat-faced berries that can't be sold on the fresh market."

The research team is now recording a more than 50% reduction in lygus damage using a two-pronged approach — a trap crop and a parasitic

Photos: Jack Kelly Clark

Sean Swezey

***Top,* in strawberry crops, growers can attract lygus bugs to a trap crop planted between rows, then use a tractor-mounted vacuum to "clean up" the pest. *Left, top to bottom,* an adult lygus bug, "cat-face" damage to a strawberry, and a parasitic wasp that infests lygus.**

CASFS/UC Santa Cruz

John Fisher

Above, **student apprentices from the UC Santa Cruz agroecology program.** ***Right,*** **more than 500 people enjoyed a dinner on the UC Santa Cruz farm during the "Back Forty: Breaking New Ground" conference in July.**

wasp — at the trial site at Larry Eddings' Pacific Gold Farms, near Salinas. The results have encouraged Eddings, one of the largest organic strawberry producers on the Central Coast, to use the approach on his conventional strawberry crops also.

Swezey says it was Jim Cochran of Swanton Berry Farm in Davenport who originally collaborated in the research, funded by the U.S. Environmental Protection Agency. The idea was to lure lygus away from the strawberries by introducing a flowering plant as a trap-crop row directly into organic strawberry fields.

Continuing with a Biologically Integrated Farming Systems (BIFS) grant from UC Sustainable Agriculture Research and Education Program (UC SAREP), Swezey ran field trials of a number of different trap crops, including radish, alfalfa and alyssum. Rows were planted in and around the edges of the strawberry fields, and when lygus bugs reached dense populations, the growers would remove the bugs with tractor-mounted vacuums. Alfalfa proved the most effective trap crop.

Researchers then tested the alfalfa trap crop approach on a portion of Eddings's organic strawberries. Devoting 2% to 3% of the strawberry field to alfalfa produced optimal results. Vacuuming only the trap crop and not the strawberries has slashed tractor time by more than 75% (in organically managed fields, the standard practice is to vacuum an entire field to remove lygus bugs). "That translates to lower labor and fuel costs, reduced emissions and preservation of the 'good bugs' that used to be vacuumed up with the lygus bugs," Swezey says.

From the beginning of his lygus research, Swezey had also been looking to improve biological control with natural enemies of the bug in the trap-crop system, and possibly for the assistance of a highly selective natural enemy. Charlie Pickett, a biocontrol specialist with the California Department of Food and Agriculture's Biological Control Program, had imported the parasitic wasp *Peristenus relictus* for release in the Central Valley to help control lygus bug infestations in cotton fields. With Pickett's help, Swezey introduced the tiny wasp, which only targets the lygus bug, to the trial at Pacific Gold Farms.

In the last 3 years, the wasp has become established in the alfalfa trap crop and adjacent strawberries; it is living on its own without new releases. More than 60% of lygus bug nymphs in the trap crop have been parasitized by the wasps, and, in conjunction with the trap crop vacuuming, lygus damage to the strawberry crop has dropped more than 50%.

Blueberry crops promising

Tours of the UC Santa Cruz farm, which was started in 1971, included a stop at a blueberry trial. "If I had to plant 5 acres of blueberries right now, I'd plant 'Southmoon'," says Jim Leap, manager of the 25-acre CASFS organic farm. "It's far and away the best-tasting blueberry" among the 15 varieties being field-tested at the campus farm, "the yield looks good on it, and it's easy to pick," he says.

Aware of Leap's interest in crops for small-scale organic growers, UCCE farm advisor Aziz Baameur approached him in 2003 with the idea of planting out a blueberry trial at UC Santa Cruz. In collaboration with UCCE farm advisor Mark Bolda, and with funding assistance from the UC Small Farm Center at UC Davis, researchers established a 0.16-acre field trial overlooking the ocean on the

CASFS *— continued next page*

CASFS
The CENTER *for* AGROECOLOGY *&* SUSTAINABLE FOOD SYSTEMS

CASFS *— continued from previous page*

CASFS farm. The trial consists of 15 blueberry varieties with a total of 180 plants.

This is the first season that yield data were collected, and the numbers have not been crunched yet, but Leap is heartened by the trial so far. Though he had to put up bird netting over the entire trial area, it looks as if organic blueberries will grow well on the Central Coast. The berries sold exceptionally well at $4 per half-pint — $6,000 worth just at the UC Santa Cruz Market Cart (at the campus entrance), and they were a popular item in the farm's CSA (community-supported agriculture) shares.

"The challenge is that blueberries need acidic soil," Leap says. Inexpensive sulfuric acid can be applied to conventionally managed blueberry fields, but Leap has had to buy vinegar approved by the Organic Materials Review Institute (OMRI) for use in certified organic systems. "We have been injecting vinegar with each irrigation. Before we planted, we applied a lot of soil sulfur and acidic soil amendments, but we still need the vinegar, and buying it in 55-gallon containers and trucking them in here might turn out to be prohibitively expensive," he says. (Also, see *California Agriculture* April-June 2005, Vol. 59, No. 2, p. 65.)

UC students eating local, organic produce

Seven farmers local to UC Santa Cruz are participating in a groundbreaking farm-to-college program, supplying organic produce to the university's five campus dining rooms and restaurant. The program is running side by side with a 2-year research study on developing institutional market outlets for small and medium-sized growers.

The first program of its kind in the UC system, this is one of many farm-to-institution initiatives sprouting up around the country. Hundreds of institutions, including K-12 schools, Kaiser Permanente and UC San Francisco hospitals, and corporate cafeterias, such as Google's in Mountain View, are offering locally and sustainably grown produce. It's still a largely untapped market, says Patricia Allen, new director of the UC Santa Cruz Center for Agroecology and Sustainable Food Systems (CASFS). "Farm-to-institution programs could be a lifeline for small to mid-scale farmers struggling to stay afloat," she says.

Jim Leap

Students participate in a "Harvest for Health" activity at the UC Santa Cruz farm, part of a core course required of all first-year students in one of the campus's residential colleges.

The seven farms supplying the UC Santa Cruz dining halls are Coke Farm, Phil Foster Ranches, Happy Boy Farms, New Natives/Greensward Nurseries, Swanton Berry Farm, Agriculture and Land-Based Training Association (ALBA), and the UC Santa Cruz farm on campus. Because the UC Santa Cruz purchasing department is not set up to contract with individual small farmers, the growers formed a consortium, Monterey Bay Organic Farming Consortium (MBOFC). ALBA acts as their umbrella organization, pooling and delivering the produce to the campus dining halls three or four times a week, invoicing the university and distributing payments to the growers.

Demand for the produce is high, from both chefs and students, but getting the program in place wasn't easy. To look in detail at the structuring and viability of institutional markets for small and medium-sized farmers, particularly those farming organically or using other environmentally sustainable farming methods, CASFS is heading up a collaborative research project. The study, which began last fall, is being funded by a $400,000 grant from the U.S. Department of Agriculture's Cooperative State Research, Education and Extension Service (CSREES). The project directors are Allen and Shermain Hardesty, director of the UC Small Farm Center.

Specifically, the research team is studying the demand among students for food from small and medium-sized farms with sustainability criteria (for example, organic, locally grown and socially just); the produce-buying practices and preferences at California's colleges and universities; and the best produce distribution models. Results from the student survey show a definite interest in organic produce. Of the 224 returned surveys from students nationally, 47% said they wanted their college to provide organic food. Most students (53%) wanted their college to provide food locally grown. But the highest interest among students was for food that was humanely produced (78%), provides a living wage to workers (71%) and sustainably produced (62%).

Hardesty, who is surveying food-service buyers at California's colleges and universities, was "very surprised," she said, to find that about 25% of the

The solution could be for the farm to make its own organic vinegar, Leap says. That's likely to be a job for the 6-month apprentices, who provide most of the labor for the farm. Forty years after the start of Chadwick's experiment, they continue to live on the edges of the well-cared-for fields at UC Santa Cruz, which has been dubbed the "Harvard of organic farming." — *Hazel White and Editors*

For more information:
http://casfs.ucsc.edu

Photos: Aziz Baameur

At the UC Santa Cruz farm, 15 varieties of blueberries are being field-tested for taste and adaptability to coastal growing conditions. *Clockwise from top left:* a blueberry cluster; a plant is pruned by a farm employee; workshop participants evaluate varieties for color, size, sweetness and other qualities.

78 buyers she has interviewed so far already have a local buying program and 15% are developing one. Most of those buyers said they were willing to pay a premium of around 25% for some organic, sustainably produced, or locally grown produce. Hardesty thinks the biggest obstacle that must be addressed for local producers to gain greater access to institutional markets is the need for a consolidated delivery system.

Gail Feenstra, food systems analyst with the UC Sustainable Agriculture Research and Education Program (SAREP), is heading up the research on distribution infrastructures for getting regional produce to institutional cafeterias. "This is very new," Feenstra says, "and it's going to take a number of years" to get the optimal infrastructures worked out, but chefs and food service directors want local food, and "some big players are starting to change their buying contracts" to include requirements for sustainably grown food.

If that trend toward sustainability criteria being part of institutional contracts continues, it will be the catalyst for significant environmental and social change. Allen foresees more than an improvement in the eating habits of millions of Americans. Contract criteria might include wage and benefits requirements for workers and reductions in toxic pesticides, she says, and then "a huge market could be transformed with an incentive-based approach, rather than through regulation."

The UC Santa Cruz farm-to-college program has adopted sustainability criteria: all the produce is grown within 250 miles of Santa Cruz and is certified organic; in addition, ALBA is a "worker-supportive" company. This year it is expected that 30% of the UC Santa Cruz dining services department's produce purchases will meet the criteria.

From the start, students have been the driving force behind the UC Santa Cruz program, but it's also true that most of the 15,000 students have never visited a farm. With funding from the True North Foundation and the Wallace Genetic Foundation, CASFS last year hired Nancy Vail to support campus education and outreach, which is helping ensure the momentum for the program continues. Demand from student meal-plan holders is the key to its ongoing success.

The UC Santa Cruz program has been successfully exported to other UC campuses. Tim Galarneau, CASFS coordinator of that effort, says commitment to sustainable food purchasing "is sweeping through the university system in a very exciting way." He reports that UC Santa Barbara and UC Davis have adopted sustainability criteria and are exploring local sourcing; Stanford University already has a contract with ALBA; and UC Berkeley is being supplied with sustainably grown food through the Growers Collaborative, which is affiliated with the Community Alliance with Family Farmers.

Galarneau is also coordinator of a statewide student movement urging the UC Regents to adopt purchasing guidelines that reflect principles of sustainability. He is also working with the housing directors on all UC campuses to develop a sustainable food policy for the entire UC system. Working collaboratively, the students, campus administrators and community organizations promise to be the strong allies local growers need to break into the farm-to-college market. — *Hazel White*

For more information:
http://casfs.ucsc.edu/farm2college

James Walsh

Loren Oki

***Left,* a portable wetland is tested to remove fertilizer and pesticides from nursery runoff; *right,* UC Davis graduate student Mike Harris collects samples from sand filtration columns. Both technologies could help limit the spread of *Phytophthora ramorum,* which causes sudden oak death.**

Regulators and researchers seek innovative water-quality solutions

The quality of California's surface waters is regulated by two agencies: the U.S. Environmental Protection Agency (U.S. EPA), under the 1972 Clean Water Act, and the State Water Resources Control Board, which was established in 1967.

Under the Clean Water Act, the federal government took responsibility to regulate point-source pollution, while calling for state and local governments to regulate nonpoint-source pollution through regional plans. As a result, federal and state agencies have taken different approaches and set somewhat different water-quality standards, whether for pathogens, sediment, nutrients, pesticides or temperature.

The federal approach is based on how much of each pollutant is allowed in a given body of water (the total maximum daily load, or TMDL). In contrast, the state approach is based on controlling pollutants throughout a given watershed. California is divided into nine major watersheds, each with its own Regional Water Quality Control Board that sets its own standards. Not surprisingly, differences can arise among water-quality regulators. For example, both federal and state pathogen regulations use indicator bacteria such as *Escherichia coli*, however federal rules are based on *E. coli* levels, while most regional boards look at all coliforms (see page 159). *— Editors*

California's perennial water woes are now critical. Contributing factors include record drought conditions in parts of the state; increasing demands from a fast-growing population; deterioration of the San Francisco Bay-Delta infrastructure; an August 2007 federal court order to protect the endangered delta smelt by dramatically reducing water deliveries to agriculture and residences; and global climate change.

"We cannot wait until we have a Katrina-like disaster to attack this problem," Governor Schwarzenegger said during a water summit with Senator Dianne Feinstein in August. In mid-September, the Governor proposed $9 billion in water-infrastructure spending; his Delta Vision Blue Ribbon Task Force will report its recommendations by January 2008.

Maintaining and upgrading the quality of surface waters is key to addressing the current crisis. To help protect streams and other surface waters, UC researchers are developing innovative, low-tech ways to control runoff pollution from farms, nurseries and cities. Runoff can carry pathogens, pesticides, nutrients and sediment, or change the temperature of waters where fish and other aquatic species spawn.

E. coli in farm runoff

Water quality often intersects with human health concerns. On Central Coast farms, for example, spinach was contaminated with a virulent strain of *E. coli* in fall 2006. These fecal bacteria can spread in water, and a leading theory holds that wild pigs may have tracked them from a nearby cattle ranch to the spinach field.

This spinach outbreak helped lead to the establishment in spring 2007 of the Center for Produce Safety, to be located at the UC Davis Western Institute for Food Safety and Security (WIFSS). The Center, which is funded primarily by the Produce Marketing Association and Taylor Farms of Salinas, will focus on facilitating information exchange, research and field training to reduce produce-related health risks.

"One issue is potential conflicts between food safety and water-quality practices," says Rob Atwill, WIFSS director and Cooperative Extension specialist

Right, **a study sponsored by the UC Davis Center for Urban Horticulture and UCCE specialist Loren Oki is evaluating California native plants for their potential as ornamentals. *Above, Ceanothus maritimus* 'Valley Violet' performed well across all of the irrigation treatments.**

in veterinary medicine at UC Davis. "For example, while vegetation between fields and streams helps control erosion and control waterborne pathogens, bare soil borders around fields reveal footprints from disease-spreading animals." To start finding common ground between these needs, WIFSS and UC Cooperative Extension (UCCE) sponsored the Management of Water Quality and Food Safety conference in April 2007 in San Luis Obispo.

The spinach outbreak also led to creation of the Leafy Greens Marketing Agreement (see page 177). Signed by handlers accounting for virtually all of California's leafy greens market, this July 2007 agreement certifies adherence to practices that reduce the risk of waterborne diseases. For example, growers avoid letting water stand in fields because it can attract animals, and they avoid the use of storm water for irrigation because it can have high levels of bacteria.

Sudden oak death in nursery runoff

Likewise, nurseries can have conflicts between plant health and water-quality practices. For example, collecting and reusing irrigation runoff could spread *Phytophthora ramorum*, the water mold that causes sudden oak death. While ultraviolet (UV) light kills *P. ramorum*, this is costly because it uses electricity and the runoff water has to be thoroughly precleaned.

To find an affordable treatment for *P. ramorum* in reclaimed nursery runoff, UC researchers are testing a two-step process adapted from other applications. The first step entails removing sediment, pesticides and many pathogens with portable subsurface wetlands. This part of the process is being tested by John Kabashima, UCCE Orange County director. Filled with gravel and planted with bulrushes, these artificial wetlands are similar to those used to treat sewage water nationwide.

"There are lots of benefits," Kabashima says. "Portable wetlands are far more efficient, and because they cover far less land area, they have fewer wildlife or mosquito problems." Moreover, their portability makes it easy to swap a clean unit for a dirty one.

The second step entails killing *P. ramorum* with slow sand filtration. This part of the process is being tested by Loren Oki, a UC Davis landscape horticulture specialist. His experimental setup comprises 6-foot vertical pipes full of sand, and water inoculated with a *P. ramorum* relative that infects pepper plants (*P. capscici*). The water also contains bacteria that eat water molds, and the sand gives these bacteria a surface to multiply on, while the slow filtration rate gives them enough time to eat all the water mold.

"It's a really old technology," Oki says. "It's simpler and cheaper than UV irradiation." Ultimately, he will use *P. capscici* to establish large colonies of bacteria that eat water mold in treatment pipes, which he will then test on stream water laden with *P. ramorum*.

Pesticides in urban runoff

UC researchers are also looking beyond agriculture to help cities qualify for their water pollution discharge permits, which are granted by the Regional Water Quality Control Boards. "First, cities hit the large businesses, such as sanitation districts, developers and nurseries," says Darren Haver, UCCE water-quality advisor in Orange County. Now cities are addressing water pollution from nonpoint sources, which is more difficult both to measure and to control.

"At the agricultural-urban interface, there's lots of fingerpointing at farms for affecting water quality,"

Photos: Darren Haver

UCCE water-quality advisor Darren Haver is assessing three demonstration landscapes for the volume of runoff and pesticides. *Left to right,* typical high-, intermediate- and low-runoff homes.

Haver says. But most farms there have been replaced by single-family homes, and while little is known about their impact on water, recent studies have revealed that urban stream sediments have high pesticide levels.

To see if there is a direct link between residential runoff and surface-water pollution, Haver built three demonstration landscapes that span the spectrum of water use. Landscapes account for about half of residential water use, and much of this flows into gutters and concrete-lined storm channels that drain directly into streams and other surface waters.

Haver designed his demonstration landscapes both to assess pollutants in residential runoff and to test recommendations for reducing runoff. His landscapes simulate: (1) a typical high-runoff home with a big lawn, automatic sprinklers, and a concrete driveway and patio; (2) an intermediate-runoff home with a small, drought-tolerant lawn, and a permeable flagstone patio; and (3) a low-runoff home with native plants, drip irrigation, and an interlocking paver driveway and patio.

Loren Oki

A large-scale study is looking at runoff in eight Sacramento and Orange County suburban neighborhoods. UC Davis program coordinator Robert Mazalewski collects a sample for analysis.

So far, the results suggest that pesticide levels are high in residential runoff. "We need to design our landscapes to keep water and pesticides on-site," Haver says. When water soaks into the ground instead of running into the gutter, the pollutants in it also stay put. That gives the pesticides time to break down into nontoxic compounds. In addition, simply conserving water, which reduces runoff, would also do a lot to safeguard streams and other surface waters.

In addition, Haver and Oki are part of a large-scale study of residential runoff. This is the first study characterizing residential runoff and it's easy to see why — it took more than 6 months just to identify the study sites. There are four neighborhood sites in Sacramento and four in Orange County, and each has 100 to 400 single-family homes and no multifamily, commercial or agricultural land.

"The beauty of this study is that each site is the residential equivalent of a watershed, with the runoff ultimately flowing into a single storm drain that then feeds into a surface water," Oki says. "This makes it possible to sample runoff from an entire neighborhood at a single point."

As in the small-scale demonstration landscape study, this large-scale neighborhood study shows that residential runoff has high levels of pesticides. "There are spikes associated with the first storms of the season," Oki says. These pesticides are pyrethroids and fipronil, which are used to control ants. Many homeowners have pest-control services that spray around the house exterior once a month, and the pesticide buildup washes away in the first rains.

By combining the results of these two studies, the researchers will determine whether outreach can reduce residential runoff. The outreach will be based on what works best in the demonstration landscapes, and will be delivered intensively to residents in half the neighborhood study sites. If this is effective, the "outreach" sites will have less runoff than the "nonoutreach" sites.

Native plant landscaping

To encourage more low-runoff landscaping in California, Oki and UC Davis graduate student Karrie Reid are identifying overlooked native plants that could appeal to mainstream gardeners. This work is part of an initiative for the commercial introduction of native plants sponsored by the UC Davis Center for Urban Horticulture, which was established in spring 2007. In contrast to native species, many nonnative garden plants need plenty of water during California's dry summers, as well as insecticides for pests that survive the mild winters. Initially, Oki and Reid are testing six native species that have performed spectacularly in the UC Davis Arboretum, including Apache plume (*Fallugia paradoxa*), a shrub with abundant 1-inch white flowers, and orange columbine (*Aguilegia eximia*), a showy perennial with 6-foot-tall flower spikes.

Finding effective ways of reducing residential runoff is increasingly important as the state's population continues to grow. "Do outreach and conservation really work?" Haver asks. "Or do we need someone to go around and give tickets?"

— Robin Meadows

For more information:

State Water Resources Control Board
www.swrcb.ca.gov

UCCE Orange County, Water Quality Program
http://ceorange.ucdavis.edu

UC Davis California Center for Urban Horticulture
http://ccuh.ucdavis.edu

Management reduces *E. coli* in irrigated pasture runoff

by A. Kate Knox, Kenneth W. Tate, Randy A. Dahlgren *and* Edward R. Atwill

Microbial pollutants, some of which can cause illnesses in humans, chronically contaminate many California water bodies. Among numerous sources, runoff from irrigated pastures has been identified as an important regulatory target for improving water quality. This study examined the potential to reduce* E. coli *contamination from cattle in irrigated pastures. During the 14 irrigation events examined, we found that* E. coli *concentrations were lowest with a combination of three treatments: filtering runoff through a natural wetland, reducing runoff rates, and letting the pasture rest from grazing at least a week prior to irrigation. Integrated pasture and tailwater management are required to significantly reduce* E. coli *concentrations in runoff.

A study at the UC Sierra Foothill Research and Extension Center examined the ability of small wetlands to filter *E. coli* in runoff from irrigated, grazed pastures. Such disease-causing pathogens pollute waterways across California.

Contamination of surface waters by pathogens — and the associated human health risks — is a leading water-quality issue for California and the nation. Pathogens are the most common impairment to surface waters in California, according to the statewide list of polluted water bodies (Cal EPA 2004). Listed pathogen-impaired water bodies include 103 miles of coastal shorelines, 4,713 acres of estuaries, 688 acres of lakes and reservoirs, and 1,788 miles of rivers and streams.

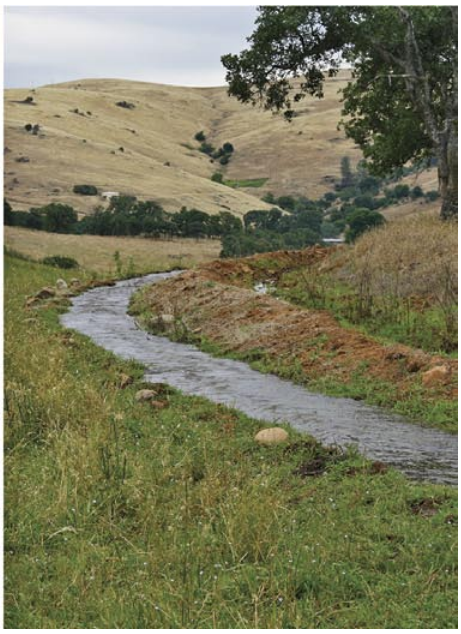
Pathogens that can cause illness in humans include protozoa such as *Cryptosporidium parvum* and *Giardia duodenalis*, as well as bacteria such as *Salmonella* and *Escherichia coli* O157:H7, a virulent strain of the commonly found coliform. The sources of these pathogens are diverse; they are shed in the feces of wildlife, humans, livestock and pets found across most watersheds. Pathogen contamination can come from point sources such as discharge from municipal wastewater treatment plants, as well as nonpoint sources such as wildlife (Atwill et al. 2001) and intensive and extensive livestock production systems (Atwill et al. 2003; Lewis et al. 2005).

Although pathogens are the underlying concern, most state and federal ambient fresh-water quality standards are based on indicator coliform bacteria. The standards use total or fecal coliforms and/or a subset of this group called *Escherichia coli*. For fresh waters such as streams and lakes across California, fecal coliform standards range from 20 to 2,000 colony-forming units (cfu) per 100-milliliter (ml) sample, depending on the designated beneficial use of the water body. For full-body-contact beneficial uses such as swimming and bathing, the U.S. Environmental Protection Agency (U.S. EPA) currently recommends an *E. coli* standard of 126 cfu/100 ml for an average of five samples collected over 30 days, or 235 cfu/100 ml for a single grab sample.

While these standards are based on the assumption that there is a correlation between these indicator bacteria and microbial pathogens of concern, the validity of this assumption likely varies from watershed to watershed as well as seasonally within a given watershed. In addition, we have a generally poor understanding of how indicator bacteria and pathogen concentrations correlate in rural or agriculturally dominated watersheds. Regardless, indicator bacteria are used as regulatory surrogates for pathogens due to their relatively low analysis costs and analytical simplicity compared to most pathogens, which can be expensive and technically difficult to test for on a large scale.

Pathogens from irrigated pastures

Recent regulatory developments in California have focused significant attention on the quality of waters discharged from agricultural production systems, including extensive livestock



The 12-acre pasture was irrigated at different rates, *above and center*, in order to measure the amount of fecal bacteria flushed from the field. Grazing was also limited prior to irrigation for varying numbers of days. *Right*, a ditch delivers irrigation water to the pasture.

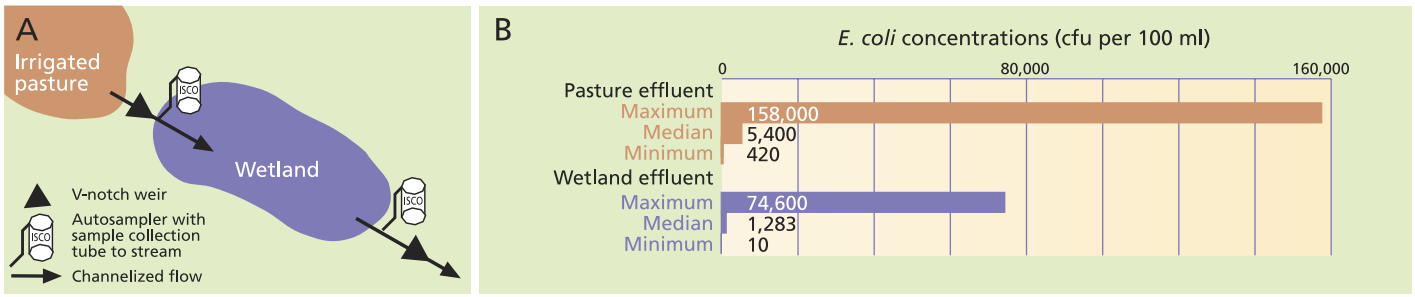


Fig. 1. (A) Wetland sampling scheme, and (B) range of *E. coli* concentrations observed at each site (cfu = colony-forming units).

production on irrigated pastures and nonirrigated rangelands. Irrigated pastures in California maintain an estimated 800,000 acres of green forage throughout the dry summer months, a critical food source for the state's livestock. While flood irrigation is a common and inexpensive way of delivering water to these pastures, this method can generate significant runoff (tailwater) (Bedard-Haughn et al. 2004; Tate et al. 2001).

Information is needed on the effectiveness of integrating three approaches to reduce microbial pollutant concentrations in tailwater discharged from pastures: (1) vegetative filters such as wetlands and buffer strips, (2) pasture grazing management and (3) irrigation management. We conducted a management-scale case study on a flood-irrigated pasture and wetland system in the northern Sierra Nevada foothills. Our objective was to examine the reduction in tailwater *E. coli* concentrations due to: (1) wetland filtration of tailwater, (2) offsetting the timing of livestock grazing and irrigation and (3) the management of irrigation-water application rates.

Study pasture and wetland

The rangeland landscape in the western Sierra Nevada foothills of Northern California is a patchwork of irrigated perennial grass and clover pastures interspersed with annual grasslands and oak woodlands. For this study, *E. coli* concentrations and instantaneous runoff rates were measured immediately above and below a flow-through wetland receiving irrigated-pasture tailwater at the UC Sierra Foothill Research and Extension Center (SFREC) in Yuba County. Cattle were excluded from the wetland for the duration of the study period, April 2004 through September 2005.

The wetland was on an ephemeral stream channel at the base of a small basin that collects runoff from a 12-acre, flood-irrigated, foothill pasture (fig. 1A). Tailwater runs directly into the ephemeral channel along the base of the irrigated pasture. Tailwater is then transported approximately 150 yards down the channel to the top of the wetland. The only source of flow in the channel during the summer irrigation season is tailwater from this irrigated pasture. Flow from this upstream channel is naturally dispersed throughout the wetland and eventually leaves via another channel at the bottom.

The wetland has a surface area of about 0.5 acre, with a flow path (the length of wetland between inflow and outflow points) of about 135 yards and an average width of 200 yards. The wetland is densely vegetated with dotted smartweed (*Polygonum punctatum*), water speedwell (*Veronica catenata*) and rice cutgrass (*Leersia oryzoides*). Due to regular irrigation events on the pasture, the wetland remains saturated throughout the summer months with standing surface water between irrigation events.

Grazing and irrigation protocols

Pasture irrigation was managed during the 2004 and 2005 summer irrigation seasons to create a range of

TABLE 1. Tailwater runoff rates and *E. coli* concentrations in irrigated pasture–wetland system for 14 irrigation trials at SFREC, 2004 and 2005

Irrigation event	Irrigation application rate	Duration of tailwater runoff	Duration of pasture rest from grazing prior to irrigation	Max. instantaneous tailwater runoff rate above wetland	Total tailwater runoff		Reduction in *E. coli* tailwater load due to wetland*
					Into wetland*	Out of wetland*	
	cfs/acre	*hr*	*day*	*cfs/acre*	*cu ft/acre*		*%*
7/1/04	2.5	5.50	9	1.38	21,800	19,250	33
7/13/04	0.7	9.00	21	0.52	14,200	11,900	91
7/27/04	1.7	6.50	0	1.02	16,300	14,700	79
9/2/04	1.7	7.50	0	1.22	29,900	26,200	64
9/19/04	0.7	11.50	16	0.60	17,200	16,350	74
10/2/04	2.5	7.75	29	1.67	37,800	34,800	63
10/17/04	0.7	8.00	0	0.47	18,450	17,200	81
6/16/05	2.5	3.50	0	1.53	—	—	—
6/29/05	1.7	4.25	8	1.19	19,200	14,700	65
7/11/05	0.7	9.75	20	0.36	—	—	—
7/26/05	0.7	4.25	35	0.68	10,450	8,700	91
8/8/05	2.5	6.00	0	1.47	20,700	16,800	69
8/19/05	1.7	6.50	9	1.00	—	—	—
8/31/05	0.7	6.75	0	0.47	8,900	7,400	90

* Because of equipment failure, a complete record of water inflow was not available for 6/16/05, 7/11/05 and 8/19/05; water outflow is not shown, and percent *E. coli* load reduction for these dates could not be accurately calculated.

water-application and tailwater-runoff rates (table 1). This allowed us to investigate the potential to reduce *E. coli* concentrations in tailwater by reducing the runoff rate, which in turn reduces the erosion of bacteria from cattle fecal pats (hydrologic mobilization) and the flushing of bacteria from the pasture in surface runoff (transport capacity). The timing of pasture grazing by beef cattle was managed to create a range of total days rest between grazing and irrigation of the pasture. This allowed us to characterize the potential reduction of *E. coli* in tailwater attributable to such processes as the background mortality rate of *E. coli*, and the drying and heating of fecal pats during the summer season (Li et al. 2005).

Grazing. The 12-acre irrigated pasture was fenced as one complete unit and was grazed by beef cattle during the 2004 and 2005 summer irrigation seasons (May through October). Grazing duration ranged from 8 to 16 days per month. The number of cattle ranged from 56 to 102, resulting in mean stocking rates per grazing event of 1.3 to 1.8 animal unit months per acre.

Irrigation. The pasture was irrigated in five discrete sections called sets, and set size ranged from 1 to 4 acres. These sets were irrigated sequentially so that the entire pasture was irrigated over the course of 2 to 3 consecutive days. Irrigation scheduling was such that the entire pasture was irrigated every 9 to 14 days throughout the summer, with the shortest intervals in July when hot temperatures and long days created the greatest plant-soil water demand.

Days of rest. The timing of grazing (once per month for 8 to 16 days) combined with the timing of irrigation (every 9 to 14 days) created a range of days of rest between grazing and irrigation. This resting period ranged from 0 to 35 days (table 1), with 0 days of rest meaning that cattle were present during irrigation. Finally, irrigation application rates of 0.7 (n = 6), 1.7 (n = 4) and 2.5 (n = 4) cubic feet per second (cfs) per acre were applied over the 14 irrigation events to create a range of tailwater runoff rates from 0.36 to 1.67 cfs/acre (table 1).

Tailwater collection. Half of the 14 irrigation events were in summer 2004 and the other half in summer 2005 (table 1). For this study, we focused tailwater monitoring on specific irrigation events in a single irrigation set that was slightly over 1 acre. Thus, we could control for variation in the area of pasture generating runoff between irrigation events, and achieve a relatively broad range of tailwater runoff rates across events. The duration of tailwater runoff per irrigation event ranged from 3.5 to 11.5 hours, and during this time samples were collected at 30- to 60-minute intervals. This allowed for the characterization of *E. coli* concentrations throughout the entire runoff period for each irrigation event.

Measuring *E. coli*. Samples were collected within the stream channel immediately above and below the wetland using ISCO 6700 autosamplers (ISCO, Lincoln, Neb.). This allowed the quantification of input-output *E. coli* concentrations and loads to evaluate the effectiveness of wetland filtration. Flow rates were continuously recorded every 15 minutes using a 1-foot, 90° V-notch weir with an automatic depth recorder (Metritape Type AGS, Metritape, Littleton, Mass.). This allowed us to examine the effect of tailwater runoff rate on *E. coli* concentration. *E. coli* concentration (cfu/100 ml) was determined within 24 hours of sample collection by direct membrane filtration and then culture of the membrane onto CHROMagar EC (Chromagar Microbiology, Paris, France) at 112.1 °F (44.5 °C) for 24 hours.

Hydraulic residence times. Hydraulic residence time, which is generally an estimate of how long water takes to

Passing tailwater through relatively small wetlands can significantly reduce *E. coli* from irrigated pastures.

Runoff below the wetland had significantly lower *E. coli* concentrations; nonetheless, 95% of the samples collected still did not meet federal standards for *E. coli*.

TABLE 2. Linear mixed effects analysis characterizing the relationship between log_{10}-transformed *E. coli* concentration (cfu/100 ml) in irrigated-pasture tailwater above and below a wetland receiving tailwater at SFREC, 2004 and 2005 irrigation seasons

Fixed variable	Coefficient*	Standard error	*P* value†
Intercept	3.74	0.094	< 0.001
Sample location			
Above wetland‡	0.00	—	—
Below wetland	–0.91	0.076	< 0.001
Tailwater runoff rate (cfs/ac)	0.18	0.071	0.014
Time since first tailwater runoff (hr)§	–0.05	0.008	< 0.001
Days rested from grazing	–0.02	0.006	0.003
Days rested from grazing^2	0.0004	0.0001	0.050
Sample location × tailwater runoff rate¶			
Above wetland‡	0.00	—	—
Below wetland	0.66	0.103	< 0.001

* Coefficient for each significant independent variable in regression model. Coefficient value indicates the effect (+ or –) and magnitude of relationship between each variable and log_{10} *E. coli* concentration. For continuous variables (tailwater runoff rate, time since first tailwater runoff per irrigation event, and days rested from grazing prior to irrigation event), the coefficient indicates the change in *E. coli* concentration associated with each additional increment in the variable (e.g., cfs/acre, hour, day).

† *P* value for each independent variable.

‡ Referent condition for categorical variable sample location. The coefficient for the referent condition (above wetland) is set to 0.0 and the coefficient for below the wetland represents the estimated reduction in log_{10} *E. coli* concentration between the sample locations above and below the wetland.

§ Time since the first tailwater runoff arrived at each sample location for the irrigation event.

¶ Interaction term for sample location by tailwater runoff rate.

pass through a wetland, can be a major factor influencing the efficiency of the wetland to retain pollutants (Blahnik and Day 2000). Longer residence times, often associated with lower runoff rates, generally result in greater retention of pollutants (Knight et al. 2000). Determining the hydraulic residence time for a study wetland allows extrapolation of the results to other wetland systems.

To quantify hydraulic residence times, continuous bromide injections were conducted at irrigation application rates of 0.7, 1.7 and 2.5 cfs/acre. Bromide is considered a conservative tracer of water movement through space and time because it is not utilized by plants or microorganisms, and is not readily bound to soil particles. A solution of known bromide concentration was injected at a known rate (20 to 25 milliliters per minute) into the center of the stream above the wetland, using a fluid-metering pump. During injections, water samples were collected at short intervals (3 to 20 minutes) to capture the entire runoff period both above and below the wetland. Bromide concentrations were quantified using ion chromatography. The hydraulic residence time was calculated using the time it took for half of the bromide to pass from above to below the wetland (Webster and Ehrman 1996). More than 95% of the bromide injected was recovered below the wetland for all three irrigation events.

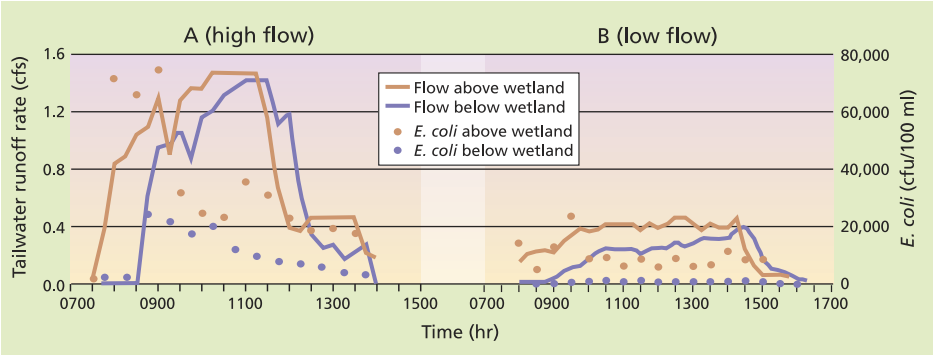
Data analysis. We used linear mixed effects regression to simultaneously examine the reduction in *E. coli* concentration by the wetland, as well as the relationships between *E. coli* concentration and instantaneous tailwater runoff rate (cfs/acre) above and below the wetland, days of rest from grazing prior to irrigation, and time of sample collection relative to the arrival of tailwater at a sample location (for more detailed methodology, see Tate, Lancaster et al. 2005, and Tate, Lyle et al. 2005). The dependent variable was *E. coli* concentration (cfu/100 ml) in water samples (n = 364) collected throughout 14 irrigation events from sample locations immediately above and below the wetland. *E. coli* concentration was log_{10} transformed. Independent or fixed effect variables in the model were sample location (above or below the wetland), tailwater runoff rate (cfs/acre), duration of rest from grazing prior to irrigation (days), and time since the arrival of tailwater runoff at each sample location for each sample collected (hours) for each irrigation event.

To assess whether wetland efficiency was dependent upon instantaneous tailwater flow rate, we included an interaction between sampling location (above versus below) and instantaneous tailwater runoff rate at the sample location. The quadratic term for days of rest from grazing was included to account for the possibility that the relationship between rest period and *E. coli* concentration was not linear. A backward-stepwise approach was followed to identify significant ($P < 0.05$) factors associated with *E. coli* concentrations. Year (2004 or 2005) was treated as a random effect variable to adjust the results for possible differences between years.

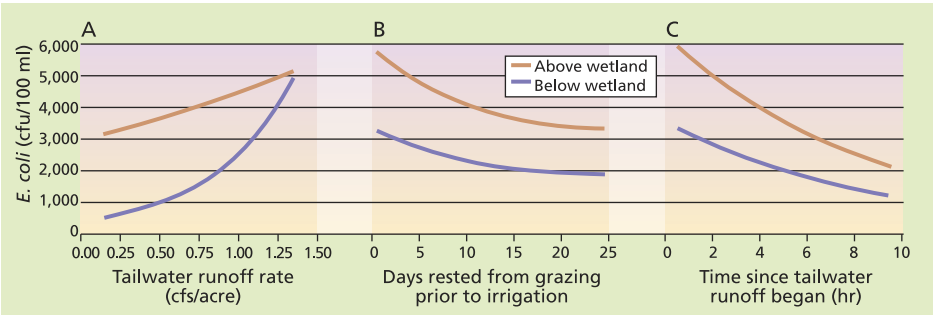
Effects on *E. coli* concentrations

Wetland filtration. *E. coli* concentrations were reduced below the wetland compared to above the wetland (table 2; fig. 2). For example, at an instantaneous tailwater flow-rate of 1.0 cfs and following 7 days of pasture rest from grazing, the final analysis found that the wetland decreased *E. coli* concentrations in tailwater by about 40% (fig. 3A).

E. coli concentrations in pasture runoff above the wetland were never below the 235 cfu/100 ml standard recommended by the U.S. EPA for any of the samples (n = 182) collected during the 14 irrigation events, ranging from 420 cfu/100 ml to 157,800 cfu/100 ml, with a median of 5,400 cfu/100 ml (see fig. 1B, page 160). In contrast, overall *E. coli* concentrations below the wetland (filtered pasture runoff and wetland runoff)



◀ **Fig. 2. *E. coli* concentration and tailwater profiles above and below the study wetland for a typical (A) high- and (B) low-flow irrigation event.**



◀ **Fig. 3. Predicted *E. coli* concentrations in pasture tailwater above and below the wetland as (A) tailwater runoff rate increases (time since first runoff 3 hours, days since grazing 7 days); (B) days rested from cattle grazing prior to irrigation increases (time since first runoff 3 hours, tailwater runoff rate 1 cfs); (C) time since tailwater runoff begins during an irrigation event (days since grazing 7 days, tailwater runoff rate 1 cfs).**

were significantly lower than those above the wetland (pasture runoff). Specifically, *E. coli* concentrations below the wetland ranged from 10 to 74,600 cfu/100 ml, with a median of 1,283 cfu/100 ml. However, in spite of the more than four-fold decrease in median *E. coli* concentrations by the wetland, only 6% of the 182 samples collected below the wetland met the U.S. EPA standard.

Although the primary regulatory concern with *E. coli* centers on concentration, it is also important to consider the reduction in *E. coli* load (the total number of *E. coli* entering and exiting the wetland) per irrigation event. We calculated the percentage of total number (cfu) of *E. coli* retained within the wetland during each event from the difference between inflow and outflow load, and found that percent reduction ranged from 33% to 91%, with an average of 73% (table 1). These results are comparable to previous findings that relatively narrow (1 to 2 yards wide) vegetative buffer strips can reduce *E. coli* and *C. parvum* in runoff by as much as 90% to 99% on California's annual grasslands under rainfall-runoff conditions (Atwill et al. 2002, 2006; Tate et al. 2004, 2006). Reductions of 80% to 99% have been seen for *E. coli* and fecal coliforms with the use of constructed surface-flow wetlands to treat municipal and

***Top left,* channelized runoff from the pasture was collected in a small basin. *Above,* V-weirs were fitted with, *left,* autosamplers to monitor *E. coli* concentrations.**

Wetlands can reduce *E. coli* runoff from irrigated pastures, but their use should be integrated with management strategies such as timing grazing prior to irrigation and minimizing the volume of irrigation tailwater.

livestock wastewater (Gerba et al. 1999; Hill 2003; Quinonez-Diaz et al. 2001).

Tailwater runoff rate. As irrigation tailwater runoff rates increased, *E. coli* concentrations increased both above and below the wetland (figs. 2 and 3A); for example, figure 2 shows the increased *E. coli* concentrations profile for an irrigation event with a peak instantaneous pasture runoff rate of 1.53 cfs/acre compared to an event with a rate of 0.47 cfs/acre. This relationship can be attributed to the fact that higher runoff rates increase the tailwater's capacity for pollutant mobilization and transport. In other studies, we have found that runoff rate is positively correlated with the load of *E. coli* and *C. parvum* discharged from cattle fecal deposits on annual grasslands under rainfall-runoff conditions (Atwill et al. 2002; Tate et al. 2004, 2006).

As the tailwater runoff rate increased, the wetland was less effective at filtering *E. coli* and reducing concentrations in tailwater (fig. 3A). Essentially, at high runoff rates, the filtration capacity of the wetland becomes overwhelmed by the mobilization and transport capacity of the tailwater. The increase in instantaneous tailwater runoff rate corresponded with a decrease in hydraulic residence time, which also likely reduced the amount of time for wetland processes that reduce *E. coli* concentrations, such as exposure to solar ultraviolet radiation and predation by other microbes.

In this wetland, the hydraulic residence time varied from 38 minutes at an irrigation-water application rate of 2.5 cfs/acre to over 120 minutes at 0.7 cfs/acre; these application rates resulted in maximum instantaneous pasture runoff rates of 1.53 and 0.47 cfs/acre, respectively. These relatively short hydraulic residence times, in conjunction with the relatively low retention of total runoff volume (table 1), indicate that the majority of tailwater runoff contributed to the wetland during an irrigation event passed through that wetland during the same event. From total water inflow and outflow volume data (table 1), we can calculate that water retention in the wetland over these irrigation events ranged from 5% to 23%, with the wetland retaining an average of 13% of the water contributed per event.

Soils at the study site were formed over greenstone with a rocky clay B-horizon at a depth of about 1 foot, and an impervious, dense clay C-horizon at a depth of about 3 feet. There is not much storage volume in the soil profile below this wetland, so that any significant water loss to vertical seepage would have to come from losses through fractured bed material. Instead, we suspect that most water retained in the wetland was lost to subsurface flows through channel substrates and lateral subsurface flow from the wetland to the surrounding soil profile. In general, we have observed that the major hydrologic transport pathways in the study site soils are significant lateral flow on top of the B-horizon and through macropores such as rodent tunnels, root tunnels and soil cracks.

Grazing. *E. coli* concentrations in tailwater directly from the pasture (above the wetland) were highest when cattle were actively grazing during an irrigation event with high tailwater runoff rates. *E. coli* concentrations in tailwater were significantly reduced with increasing rest time between grazing and irrigation (table 2, fig. 3B). However, the relationship was not linear, and *E. coli* reductions became smaller with each additional day of rest. For example, the *E. coli* concentration was 23% lower after 9 days of rest than after 1 day of rest, but only 2% lower after each additional day of rest. This reduction was likely due to two primary processes: (1) as cattle fecal pats age, the microbial pollutants in them naturally die off (Li et al. 2005; Meays et al. 2005), and (2) as the pats dry, they develop shells that trap the bacteria inside.

Irrigation events. Over the course of an irrigation event, *E. coli* concentrations initially spiked but then declined (figs. 2 and 3C). This pattern is likely due to two primary processes: (1) as the irrigation event progresses, the tailwater volume increases and dilutes the *E. coli*, and (2) as the first irrigation water flows, it flushes the readily mobilized and transportable bacteria from the pasture.

This result shows the importance of collecting multiple samples during an irrigation event to accurately characterize *E. coli* concentrations. In addition, a single sample near the end of the event will be much more likely to achieve water-quality standards than a single sample collected early in the event.

Attaining water-quality standards

Results from this study indicate that passing tailwater through relatively small wetlands can significantly reduce *E. coli* from irrigated pastures. As with any management measure, the feasibility and costs of creating a wetland will be site-specific. However, wetlands reduce *E. coli* concentrations less efficiently as the tailwater runoff rate increases. In addition, the concentration of *E. coli* in pasture runoff increases with the tailwater runoff rate. Collectively, these results indicate that the implementation of a wetland filter to reduce pathogens should be integrated with irrigation management designed to minimize tailwater runoff rates and volume. Simply implementing a wetland filter under conditions of high tailwater runoff rates may not lead to significant reductions in *E. coli* concentrations discharged from irrigated pastures (fig. 3A). This study also indicates that allowing several days of rest from grazing prior to irrigation can significantly reduce *E. coli* in pasture runoff.

We found that the combination of a wetland filter, low tailwater runoff rates, and at least 1 week of rest from grazing prior to irrigation generated the lowest *E. coli* concentrations. Nonetheless, 94% of the 182 samples collected below the wetland during 14 irrigation events were above the U.S. EPA recommended level of 235 cfu/100 ml. (California water quality is now regulated by nine regional boards with differing standards; these standards also differ from the federal recommendations [see p. 156].) Under the grazing and irrigation conditions of this study, we also found that up to 91% of the total *E. coli* load discharged from the pasture was filtered by the wetland, with 73% filtered on average per irrigation event. It is critical to fully explore opportunities to further reduce tailwater runoff rates and subsequent *E. coli* generation from irrigated pastures, allowing wetlands to serve as efficiently as possible.

Finally, it is important to note that the standard *E. coli* test is used to identify indicator bacteria rather than a specific pathogen of concern. We have found *E. coli* concentrations in beef cattle feces on irrigated pastures to be as high as 500,000 to 1,000,000 cfu per gram of wet feces. It is therefore not uncommon to find relatively high *E. coli* concentrations in pasture tailwater, particularly when the feces are fresh and tailwater runoff rates are high.

The critical questions that must be addressed focus on the load and concentrations of actual pathogens in tailwater, and the efficiency of integrated wetland, irrigation and grazing management to reduce the pathogens that may be discharged from pastures during irrigation events. For instance, in California's beef cattle herds, *C. parvum* oocysts (eggs) are primarily shed in high concentrations in the feces of beef calves 1 to 4 months old, with very low shedding rates for adult cattle (Atwill et al. 1999, 2003). In contrast, *E. coli* indicator bacteria are consistently shed in all ages of cattle feces at high rates year-round. A grazed pasture might discharge high concentrations of indicator bacteria, but low or zero concentrations of the pathogen *C. parvum*.

Without such information on all pathogens of concern, it is possible that regulation based upon indicator bacteria alone will lead to unnecessary management restrictions. Alternatively, if indicator bacteria are poorly correlated with certain pathogens, it is also possible that regulation based solely upon indicator bacteria will lead to a false sense of human health protection. This suggests that water-quality monitoring and standards should target specific microbial pathogens of concern.

A.K. Knox was Graduate Student in Ecology, UC Davis, and now is Ecologist, WSP Environmental Strategies, Seattle, Wash.; K.W. Tate is Rangeland Watershed Specialist, Department of Plant Sciences; R.A. Dahlgren is Professor of Soil Science, Department of Land, Air and Water Resources; and E.R. Atwill is Cooperative Extension Specialist and Director, Western Institute of Food Safety and Security, School of Veterinary Medicine; all at UC Davis.

References

Atwill ER, Hoar B, Pereira MGC, et al. 2003. Improved quantitative estimates of low environmental loading and sporadic periparturient shedding of *Cryptosporidium parvum* in adult beef cattle. Appl Env Microbiol 68:4604–10.

Atwill ER, Hou L, Karle BM, et al. 2002. Transport of *Cryptosporidium parvum* oocysts through vegetated buffer strips and estimated filtration efficiency. Appl Env Microbiol 68:5517–27.

Atwill ER, Johnson EM, Klingborg DJ, et al. 1999. Age, geographic and temporal distribution of fecal shedding of *Cryptosporidium parvum* oocysts in cow-calf herds. Amer J Vet Res 60:420–5.

Atwill ER, Maldonado Camargo S, Phillips R, et al. 2001. Quantitative shedding of two genotypes of *Cryptosporidium parvum* in California ground squirrels. Appl Env Microbiol 67:2840–3.

Atwill ER, Tate KW, Pereira MGC, et al. 2006. Efficacy of natural grass buffers for removal of *Cryptosporidium parvum* in rangeland runoff. J Food Protect 69:177–84.

Bedard-Haughn A, Tate KW, van Kessel C. 2004. Using ^{15}N to quantify vegetative buffer effectiveness for sequestering N in runoff. J Env Qual 33:2252–62.

Blahnik T, Day J. 2000. The effects of varied hydraulic and nutrient loading rates on water quality and hydrologic distributions in a natural forested treatment wetland. Wetlands 20:48–61.

[Cal EPA] California Environmental Protection Agency. 2004. 2002 Clean Water Act Section 303(d) List Summary Tables. State Water Resources Control Board; Water Quality. www.swrcb.ca.gov/tmdl/303d_sumtables.html.

Gerba CP, Thurston JA, Falabi JA, et al. 1999. Optimization of artificial wetland design for removal of indicator microorganisms and pathogenic protozoa. Water Sci Technol 40:363–8.

Hill VR. 2003. Prospects for pathogen reductions in livestock wastewaters: A review. Crit Rev Env Sci Technol 33:187–235.

Knight RL, Payne WVE, Borer RE, et al. 2000. Constructed wetlands for livestock wastewater management. Ecolog Eng 15:41–55.

Lewis DJ, Atwill ER, Lennox MS, et al. 2005. Linking on-farm dairy management practices to storm-flow fecal coliform loading for California coastal watersheds. Env Monitor Assess 107:407–25.

Li X, Atwill ER, Dunbar LA, et al. 2005. Seasonal temperature fluctuation induces rapid inactivation of *Cryptosporidium parvum*. Env Sci Technol 39:4484–9.

Meays CL, Broersma K, Nordin R, Mazumder A. 2005. Survival of *Escherichia coli* in beef cattle fecal pats under different levels of solar exposure. Range Ecol Manage 58:279–83.

Quinonez-Diaz MD, Karpiscak MM, Ellman ED, Gerba CP. 2001. Removal of pathogenic and indicator microorganisms by a constructed wetland receiving untreated domestic wastewater. J Env Sci Health Part A–Toxic/Hazardous Substances & Env Eng 36:1311–20.

Tate KW, Atwill ER, Bartolome JW, Nader GA. 2006. Significant *E. coli* attenuation by vegetative buffers on annual grasslands. J Env Qual 35:795–805.

Tate KW, Lancaster DL, Morrison J, Lyle DF. 2005. Monitoring helps reduce water quality impacts in flood-irrigated pasture. Cal Ag 59:168–75.

Tate KW, Lyle DF, Lancaster DL, et al. 2005. Statistical analysis of monitoring data aids in prediction of stream temperature. Cal Ag 59:161–7.

Tate KW, Nader GA, Lewis DJ, et al. 2001. Evaluation of buffers to improve the quality of runoff from irrigated pastures. J Soil Water Cons 55:473–8.

Tate KW, Pereira MGC, Atwill ER. 2004. Efficacy of vegetated buffer strips for retaining *Cryptosporidium parvum*. J Env Qual 33:2243–51.

Webster JR, Ehrman TP. 1996. Solute dynamics. In: Hauer FR, Lamberti GA (eds.). *Methods in Stream Ecology.* San Diego, CA: Academic Pr. p 145–60.

REVIEW ARTICLE

Juniper removal may not increase overall Klamath River Basin water yields

by Timothy J. Kuhn, Kenneth W. Tate, David Cao, *and* Melvin R. George

Based on published research and watershed assessment techniques, we evaluated the feasibility of augmenting water yields in the Klamath River and its major tributaries by removing western juniper, which has expanded dramatically within the Klamath River Basin over the past 130 years. The results suggest that the conversion of western juniper woodlands to shrublands or grasslands would not substantially increase water yields for the Basin as a whole. However, researchers should further examine the potential for juniper management to increase both summer flow rates in small tributaries and spring flows that support small wetlands across the upper Basin; other possible benefits could include restoring wildlife in sagebrush-rangeland habitat, reducing wildfire risks and increasing the land available for livestock grazing.

In the Klamath River Basin, water for irrigation, power, drinking and wildlife is scarce, and competition for this limited resource remains intense. In recent decades, the range of native juniper (background), a water-demanding tree, has expanded in the region due to fire suppression and land-use changes.

Recent droughts in the western United States have highlighted the overall scarcity of surface and groundwater supplies, and intensified the conflict between competing water-use demands. Regional water shortages could increase during this century, given the reduced precipitation and increased temperatures forecast by some climate change models. The Klamath River Basin (fig. 1) provides a prime example of the challenges created by an inadequate water supply, particularly in a region with multiple competing uses, such as salmon fisheries, farming, livestock production and power generation.

In 2001, for example, water shortage forecasts in the Klamath River resulted in the closure of agricultural irrigation supplies in order to maintain adequate in-stream flows for salmon runs. Levy (2003) reported that this closure resulted in agricultural losses exceeding $200 million. Conversely, in 2002 water was rationed to irrigation rather than to in-stream flows. This resulted in one of the worst fish kills in western U.S. history, claiming more than 30,000 salmon and steelhead in the lower Klamath River (Levy 2003). The conflict over Klamath River water continues: Recent federal advisory committee recommendations to protect fish species resulted in major cutbacks on commercial salmon fishing along 700 miles of California and Oregon coastline, significantly affecting the economies of coastal fishing communities.

Western juniper control

Stakeholders throughout the Basin are interested in watershed management alternatives to increase flow volumes in the Klamath River and its major tributaries. Some land managers are considering or have been restoring sagebrush rangelands by removing western juniper (*Juniperus occidentalis*) in arid tributaries of the eastern Klamath River Basin where it has become dominant due to fire suppression (figs. 1 and 2). Western juniper is a water-demanding evergreen tree that was historically restricted across northeast California and eastern Oregon by naturally occurring fires. However, fire prevention and control in the region have allowed western juniper to increase in extent and dominance over the past 130 years (Miller et al. 2005). One possible consequence of increased juniper dominance is that a greater portion of precipitation falling in these arid subbasins is used by juniper trees, resulting

Glossary

Evapotranspiration: The sum of transpiration and evaporation of water from a watershed or site.

Interception: The portion of precipitation retained by vegetation canopy or litter and lost from a watershed or site as evaporation.

Stemflow: The portion of precipitation that reaches the soil surface by flowing down the stems of trees, shrubs, forbs or grasses.

Throughfall: The portion of precipitation that reaches the soil surface by passing through, or dripping from, vegetation canopy.

Transpiration: The process by which plants take water from the soil through their roots and lose it to the atmosphere via their leaves.

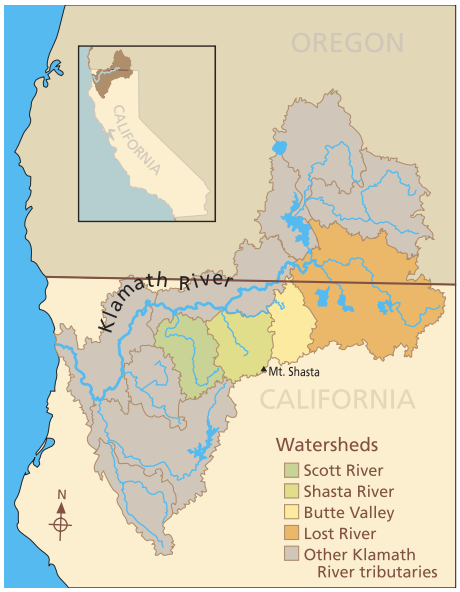


Fig. 1. The Klamath River Basin and the Scott River, Shasta River, Butte Valley and Lost River watersheds of Northern California and southern Oregon.

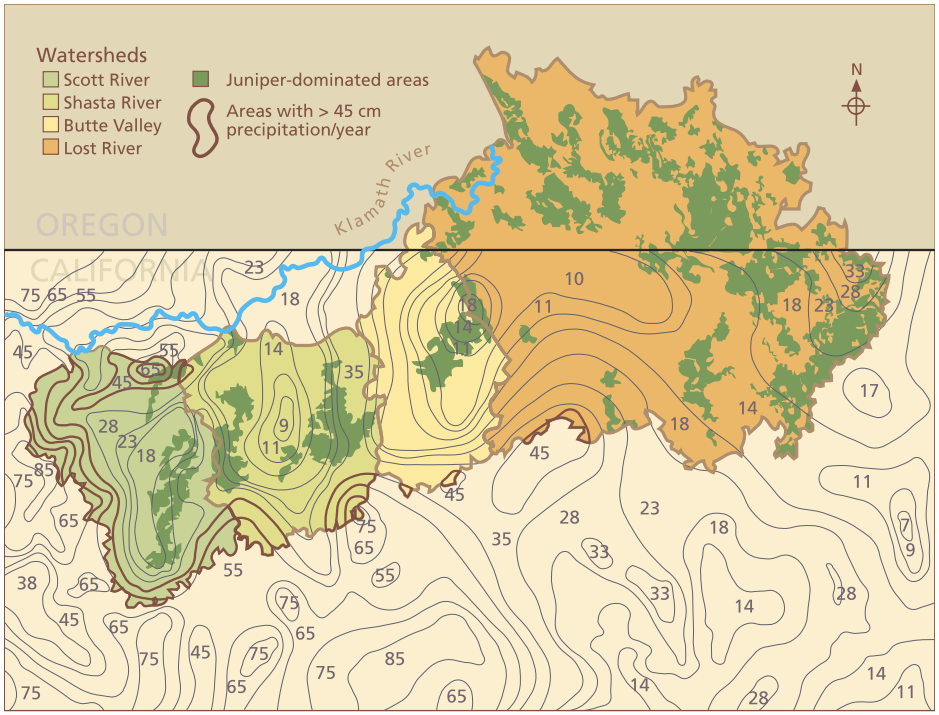


Fig. 2. Juniper-dominated areas and isohyetals (lines) showing total average annual precipitation (centimeters) within California for the Scott River, Shasta River, Butte Valley and southern Lost River watersheds. Bold isohyetals show watershed portions with more than 45 centimeters (17.7 inches) of annual precipitation. Only a small area in the northern Scott River watershed has both juniper dominance and greater than 45 centimeters (17.7 inches) annual precipitation.

in reduced stream flows and groundwater recharge (Bosch and Hewlett 1982; Wilcox 2002).

Replacing a relatively high water-use vegetation community such as juniper with a lower water-use community such as grasses is a common strategy to reduce plant-related water losses (Hibbert 1983). Reducing juniper densities can also provide other ecological and economic benefits, including increased forage production and quality for livestock and native wildlife, enhanced plant diversity, and reduced bare soil and erosion (Bates et al. 2000; Vaitkus and Eddleman 1987; Pierson et al. 2007).

The general expectation of ecological and hydrological benefits has led to hundreds of relatively small (1 to 1,000 acre) projects designed to convert juniper to sagebrush- or grass-dominated communities across the four arid watersheds of the Klamath River Basin located in California (figs. 1 and 2), as well as in the Oregon portion of the Basin. Most juniper control projects involve prescribed burning and cutting, and some are a combination of cutting and the removal of downed trees by prescribed burning.

We utilized existing research results to examine the possible hydrological consequences of increased juniper dominance in an arid to semiarid watershed, and the circumstances under which significant water-yield increases can be expected from juniper reduction projects such as those occurring in the Klamath River Basin. To assess the feasibility of augmenting Klamath River flows by removing juniper from these watersheds, we combined these research results with available rainfall and vegetation-dominance data for the major juniper-populated watersheds within the California portion of the Klamath River Basin.

Impacts on stream flow

Vegetation type is one factor that influences key hydrological processes that determine stream flow or water yield from a watershed. The water balance equation (Equation 1) accounts for the precipitation and subsequent water transport and storage, within as well as loss from, the watershed. Using this equation, Wilcox (2002) depicted the connection between vegetation and water budgets:

$$P = ET + R + G + \Delta S \quad \text{(Equation 1)}$$

The volume of precipitation (P) falling on a watershed is equal to the sum of ET or water lost by evapotranspiration (including evaporation from surface water, soil surface or vegetation surfaces [E] and transpiration by plants [T]), surface runoff as stream flow (R) or stored as groundwater (G) and change in soil water (ΔS).

Eddleman et al. (1994) stated that, depending on the type, density and distribution of the vegetation that juniper invades, hydrological consequences may include increased vegetative interception, and a greater volume of water annually transpired and evaporated from juniper-dominated sites. While deep-rooted woody vegetation such as juniper tends to reduce water yields, a mix of shallow-rooted grasses and water-use-efficient shrubs tends to optimize water yields (Hibbert 1983). Conversion to less-water-demanding vegetation types affects site hydrology by: (1) decreasing leaf area and biomass, thereby reducing the amount of precipitation intercepted by vegetation canopy and lost due to evaporation (E), and (2) reducing the amount and depth from which water is withdrawn from the soil by transpiration (T) (Wilcox 2002). By reducing evapotranspiration, conversion to such low-water-use vegetation would potentially increase runoff, groundwater recharge and soil water storage.

Missy Merrill-Davies/UC Cooperative Extension Modoc County

Numerous juniper removal projects have been implemented in the Klamath River Basin, including by cutting and prescribed burning.

However, this method of increasing water yield to arid watersheds in the eastern Klamath River Basin must be applied cautiously. Examining studies in arid and semiarid lands, Hibbert (1983) concluded that less than 1% of rangelands in the western United States are conducive to being successfully managed for increased water yield by vegetation conversion.

In arid watersheds, the potential to increase stream flow is complicated by high evaporation potential, high percentage of bare ground, and high direct evaporation of soil water (Bosch and Hewlett 1982; Hibbert 1983; Wilcox et al. 2002). Evaporation potential in arid watersheds can be so high that even when woody plant removal reduces transpiration, any soil water made available is then stored in the soil profile, directly evaporated from the soil profile, and/or used by the plants that replace the woody vegetation. Under these circumstances, increased stream flow or groundwater recharge is not realized. Likewise, Huxman et al. (2005) reported that as woody vegetation was removed from an arid site, soil water evaporation was increased due to reduced soil surface shading. Huxman et al. (2005) also found that reduced tree canopies increased wind velocities at ground level, which enhanced transpiration by herbaceous plants and evaporation from bare soil.

Impact of juniper expansion

During the past century in the Northwest, including the upper Klamath River Basin, the area occupied by western juniper has roughly doubled (Miller et al. 2005). Larsen (1993) postulated that the actual expansion rate in central Oregon was greater than 24,000 acres (9,712 hectares) per year. Miller and Rose (1995) reported that over 97% of western juniper woodlands in Oregon were dominated by trees less than 100 years old, indicating a massive recruitment of juniper during the past century of fire suppression. Although the range of juniper has shown considerable fluctuations in the past, recent expansion differs in that it is occurring under increasingly dry conditions (Miller and Wigand 1994). This expansion has been attributed to climate change, fire suppression and excessive grazing (Burkhardt and Tisdale 1976; Miller and Rose 1995). Once junipers are established at a site, their dominance appears to be essentially unaffected by competition from other plant species (Miller and Wigand 1994).

The shift to juniper dominance reduces the biomass and productivity of understory vegetation, as well as soil surface cover (Vaitkus and Eddleman 1987). This increased bare ground may reduce soil surface infiltration rates, which in turn would increase overland flow and reduce soil water storage. Pierson et al. (2007) found that even at lower rainfall rates, juniper-dominated hillslopes produced significantly more soil surface runoff and erosion than hillslopes with juniper removed in southeast Oregon.

Juniper evapotranspiration

Overall, evapotranspiration (ET) is the dominant water-budget component affected by juniper encroachment and juniper control projects. Evapotranspiration is composed of the following components: interception (I), evaporation (E) and transpiration (T) (Huxman et al. 2005; Wilcox 2002):

$$ET = I + E + T \quad \text{(Equation 2)}$$

Interception and evaporation. Estimated interception by juniper trees varies considerably, and most published studies have focused on measuring interception by individual trees rather than at the watershed scale (table 1). Eddleman et al. (1994) reported that interception rates are largely dependent on factors such as vegetation size, distribution and density, as well as storm intensity, duration and precipitation type. Interception can be separated into four components: canopy interception, litter interception, throughfall (leaf drip) and stem flow. Vegetation on-site following juniper removal determines the long-term changes in interception. For instance, big sagebrush (*Artemisia tridentata*) is a common dominant shrub where juniper is expanding, and it exhibits similar interception rates to those

TABLE 1. Summary of results for juniper interception studies

Research	Vegetation type	Canopy description	Interception
			. . . . . % . . . . .
Skau (1964)	*Juniperus deppeana*	Canopy cover 8–58%	2–25
Young et al. (1984)	*Juniperus occidentalis*	29.7 feet (9 meters) high; 33 feet (10 meters) canopy diameter	42
Larsen (1993)	*Juniperus occidentalis*	Canopy cover 9–43%	9–15
Hull (1972)	*Artemisia tridentata*	~ Density was 2.2 plants/y^2	69 (rainfall) 61 (snowfall)
West and Gifford (1976)	*Artemisia tridentata*	Not provided	31

TABLE 2. Estimated evapotranspiration (ET) for juniper

Research	Vegetation type	ET*
		%
Gifford (1975)	Pinyon-juniper	63–97
Lane and Barnes (1987)	*Juniperus osteosperma* and *Juniperus deppeana*	80–100
Thurow and Hester (1997)	*Juniperus pinchottii* and *Juniperus ashei*	100

* As % of annual precipitation.

TABLE 3. Western juniper–dominated area within Klamath River Basin (California) watersheds

Watershed	Total area	Western juniper–dominated
	square miles	*square miles (%)*
Butte Valley	603	69 (11)
Scott River	814	77 (10)
Shasta River	795	140 (18)
Lost River	1,655	346 (20)

reported for western juniper (table 1). The determining factor is how the total vegetative surface area (juniper plus sagebrush) changes due to juniper encroachment and subsequent removal.

Total interception does not represent total evaporative loss, because some intercepted precipitation may reach the ground as throughfall or stem flow. While throughfall could be intercepted by litter below the tree canopy and then be lost to evaporation, stem flow will most often reach the soil profile. Young et al. (1984) and Larsen (1993) documented juniper stem flow to be less than 5% of total precipitation, but suggested it still may provide a significant advantage for juniper growth.

Important factors determining the amount of precipitation intercepted by juniper canopy during an individual storm event are storm intensity (precipitation rate), depth and duration. The canopy of each juniper has a certain interception capacity, and once this capacity is filled, any additional precipitation will reach the soil surface as throughfall or stem flow. Estimations of annual interception by juniper in a watershed must account for the number of storms that exceed the available interception capacity.

There is little published information on the effect of storm intensity, depth and duration on interception by juniper. However, these factors vary significantly across the four major tributary watersheds of the Klamath River Basin in California. For example, from the western edge of the Scott River watershed to the eastern edge of the Lost River watershed (fig. 2), the depth of precipitation ranges from 0.9 inches (2.3 centimeters) to 2.0 inches (5.1 centimeters) for a 6-hour storm event occurring on average every 2 years (NOAA 1973). For a 24-hour storm event occurring on average every 2 years, the depth of precipitation ranges from 1.9 inches (4.8 centimeters) to 4.5 inches (11.4 centimeters) (NOAA 1973).

While interception and subsequent evaporative losses for western juniper litter on the soil surface are not known, interception by juniper litter may be considerable and possibly even greater than that by the canopy. Gifford (1970) reported that for closed canopies of pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*), 3.8 inches (9.6 centimeters) of precipitation penetrated only 9.8 inches (25 centimeters) into litter averaging 15 inches (38 centimeters) deep, never reaching the mineral soil surface. Conversely, for broken canopies at similar input volumes, water penetrated 59 inches (150 centimeters) into the soil profile. Thurow and Hester (1997) speculated that precipitation from most low-intensity, short-duration storms does not infiltrate into the soil profile due to canopy and litter interception.

Transpiration. Water losses from transpiration can be substantial (table 2) because western juniper is evergreen and possesses a root system that can readily exploit soil moisture throughout the soil profile (Miller et al. 1990; Young et al. 1984).

Increased transpiration affects water budgets by increasing the soil-water recharge demand (deficit) and reducing stream flow or groundwater recharge. Transpiration is driven by the moisture gradient (water potential) from moist soils near the roots to dry atmosphere at the leaf surface. Thus, transpiration rates are dependent upon soil moisture, relative humidity and air movement, which vary from site to site as well as across seasons and years. In southeastern Oregon juniper woodlands, Bates et al. (2000) illustrated a clear pattern of seasonal soil moisture depletion from April through September due to juniper transpiration, and the subsequent reduction in transpiration rates as soil moisture was depleted.

Conversion and water yield

Mixed findings. We found no quantitative studies assessing the conversion of western juniper for water yield augmentation. This represents an obvious gap in our knowledge of the feasibility of increasing water yields by removing western juniper in the Klamath River Basin. However, four studies have reported results on other juniper species in the western United States. These four juniper conversion projects had variable results, which could be attributed to differences in geographic location, precipitation regime, soil and geologic type, as well as in removal and post-removal activities (Hawkins 1987).

First, in a 12-year study of a southeastern Arizona watershed that was approximately 213 square miles (551 square kilometers), Collings and Myrick (1966) found no significant increase in annual water yield following juniper (*J. osteosperma* and *J. deppeana*) removal by cutting and prescribed burn. Annual precipitation at the study site was 20 inches (51 centimeters).

Second, in a 5-year study, Gifford (1975) examined storm runoff volumes from 1-acre (0.4-hectare) sites in southern Utah following juniper control by chaining (dragging a heavy chain between two bulldozers) with downed trees left on-site, compared to chaining with downed trees either left on-site or windrowed (piled into long rows). No information regarding mean annual precipitation was reported for either site. Gifford reported a 1.2- to 5-fold increase in runoff for the chained-with-windrowing treatment. No changes in runoff were observed where downed trees were left on-site after chaining, because the debris detained runoff and enhanced infiltration.

Third, Baker (1984) reported on a 14-year study of water yield following Utah juniper control with herbicide

treatment on a 363-acre (147-hectare) subbasin in central Arizona. Average annual precipitation at the site was 18 inches (46.3 centimeters). Baker found an increase in annual stream flow of 157% in the first 2 years posttreatment, which was apparent but not statistically significant 8 years posttreatment.

Fourth, Dugas et al. (1998) documented a direct reduction in evapotranspiration by removing Ashe juniper (*Juniperus ashei*) cover on central Texas plots that were 0.6 square mile (1.5 square kilometers) with annual precipitation averaging 26.5 inches (67.3 centimeters). In this study, juniper removal caused an overall decrease in evapotranspiration by only 0.003 inch (0.07 millimeter) per day. A sustained reduction in evapotranspiration rates was limited due to the increased growth of herbaceous vegetation following juniper removal.

Rainfall is key. In an extensive review of 94 conversion experiments in various vegetation types, Bosch and Hewlett (1982) found no increases in water yield in areas averaging less than 17.7 inches (45 centimeters) of annual precipitation. Hibbert (1983) concurred with these findings, and reported that mean annual precipitation could be used as a principal determinant for the potential success of augmenting water yield. Wilcox (2002) further stressed that there is little prospect of increasing stream flows where mean annual precipitation is less than 19.7 inches (50 centimeters).

How much removal? The literature on how much juniper removal is required to increase water yields is limited. Bosch and Hewlett (1982) proposed that the amount of vegetative cover removed is proportional to changes in water yield and that, for many areas, removing less than 20% of the cover would not yield detectable changes in stream flows. In contrast, Hibbert (1983) reported that the relationship between percentage of vegetation removed and reduced transpiration is nonlinear, and that meaningful reductions in transpiration in arid environments are only achieved at high levels of removal. For instance, removing half of the deep-rooted vegetation may hypothetically result in only a 20% reduction in transpiration.

Missy Merrill-Davies/UCCE Modoc County

This review and analysis found that even the complete removal of juniper is not likely to significantly increase water yields in the California portion of the Klamath River Basin. *Above,* the Big Juniper drainage, between Alturas and Likely.

Hibbert also cautioned that tradeoffs exist between canopy removal and soil water evaporation because as greater amounts of canopy are removed, increases in solar radiation and wind energy may in turn increase the direct evaporation of soil moisture. It is critical that postremoval site evapotranspiration be maintained at low levels by converting residual vegetation to types that demand lower volumes of water. Hibbert recommended following juniper removal with the active seeding of grasses or other low-water-use vegetation. Dugas et al. (1998) suggested grazing treated sites to further limit the evapotranspiration demands from herbaceous plants.

Conversion may not increase water

Research published to date indicates that increasing water yields by juniper conversion is only feasible in portions of the Scott River, Shasta River, Butte Valley and southern Lost River watersheds where annual precipitation is greater than 17.7 inches (45 centimeters) (Bosch and Hewlett 1982; Hibbert 1983; Wilcox 2002). The primary mechanisms of water yield increase are reduced precipitation interception, evaporation and transpiration. In order to apply this information to the four Klamath River tributaries in California that have significant areas dominated by juniper woodland, we sought to: (1) identify the areas dominated by juniper, (2) determine which areas have average annual precipitation above 17.7 inches and (3) determine the extent of overlap between the juniper-dominated areas and those receiving greater than 17.7 inches of annual precipitation.

We used a geographic information system (ArcGIS 9.0) to manage and overlay available spatial data layers of: (1) watershed boundary, (2) dominant vegetation and (3) annual precipitation for the portion of the Klamath River Basin defined by the boundaries of the Scott River, Shasta River, Butte Valley and southern Lost River watersheds within California. We did not consider portions of the Klamath River Basin within Oregon due to significant differences in the scale of available spatial vegetation data for the two states. The Gap Analysis of Mainland, Calif. (CSGA 1998) was utilized to delineate the areas of these watersheds dominated by juniper (minimum mapping unit greater than 247 acres [100 hectares]). Annual precipitation data for these watersheds was obtained from CSIL (2000), and lines connecting points of equal precipitation (isohyetal precipitation lines) were estimated for the four watersheds.

We defined mapping units as dominated by western juniper when they had greater than 20% western juniper canopy (CSGA 1998) (fig. 2, table 3). Western juniper dominance was not observed in lower portions of the Klamath River Basin due to high precipitation in this area.

Based upon this analysis (fig. 2), we found that only 4,438 acres (1,796 hectares) within the 520,000-acre Scott River watershed are dominated by juniper and have greater than 17.7 inches of annual precipitation. There are no areas within the Shasta River, Butte Valley or southern Lost River watersheds that meet these requirements for expected water-yield increase by juniper removal. Only small areas in the extreme southern portion of these watersheds even have annual precipitation greater than 17.7 inches. Based upon this assessment and the assumptions stated, we can find no strong evidence that water yield from these watersheds can be substantially increased by even the complete removal of juniper.

However, it is important to remember the limitations of this analysis. First, there were substantial data and research gaps in our knowledge of how western juniper influences the hydrology and water budgets of watersheds in this region of Northern California. For example, field studies are needed at multiple spatial scales (from small catchments to entire watersheds) to examine how the water budget is affected by factors such as juniper coverage, age distribution and management; associate vegetation type; soil and geology; and precipitation amount, intensity and duration. In addition, the spatial scale used in this analysis was coarse, constrained by available vegetation data (> 247-acre minimum mapping unit) and in particular by precipitation data with a maximum reliable scale of 1:100,000 (CSIL 2000). Opportunities for small-scale water yield increases (such as increasing spring-wetland flow and extent in small catchments) cannot be adequately evaluated with the available data.

Our observations, and the experience of on-the-ground land managers, is that small increases in base flow and spring-associated stream flows have been realized after juniper conversion and wildfire in areas of the Lost River watershed. These increased flows are measured on the scale of tenths of a cubic foot per second of summer base flow in perennial streams, and increased duration of summer flow on intermittent streams. Although insignificant in the arena of increasing Klamath River flows, these flows are extremely critical for maintaining aquatic habitat and drinking water for wildlife as well as livestock. Given the importance and potential ecological and range management benefits of enhanced surface-water flows in this arid region, and the potential wildlife habitat and range quality improvements that could result from juniper removal, field-based research should be conducted to improve our understanding of the role that juniper plays in local hydrology and the opportunities for managing juniper to augment local soil moisture and surface flows.

T.J. Kuhn is Graduate Student Researcher, and K.W. Tate is Rangeland Watershed Specialist, Department of Plant Sciences, UC Davis; D. Cao is GIS Specialist, SWCA Environmental Consultants, Sacramento; and M.R. George is Range and Pasture Specialist, Department of Plant Sciences, UC Davis.

References

Baker MB. 1984. Changes in stream flow in an herbicide-treated pinyon-juniper watershed in Arizona. Water Resources Res 20:1639–42.

Bates J, Miller RF, Svejcar T. 2000. Understory dynamics in cut and uncut western juniper woodlands. J Range Manage 53:119–26.

Bosch JM, Hewlett JD. 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. J Hydrol 55:3–23.

Burkhardt JW, Tisdale EW. 1976. Causes of juniper invasion in southwestern Idaho. Ecology 57:472–84.

Collings MR, Myrick RM. 1966. Effects of juniper and pinyon eradication on stream flow from Corduroy Creek basin, Arizona. US Geol Surv Prof Pap 491-B, 12 p.

[CSGA] California State Gap Analysis. 1998. USGS Biogeography Lab—California gap analysis. Data extracted March 2005. www.biogeog.ucsb.edu/projects/gap/gap_home.html.

[CSIL] California Spatial Information Library. 2000. Precipitation. Data extracted March 2005. http://casil.ucdavis.edu/casil/gis.ca.gov/teale/precipa.

Dugas WA, Hicks RA, Wright P. 1998. Effect of removal of *Juniperus ashei* on evapotranspiration and runoff in the Seco Creek watershed. Water Resources Res 34:1499–506.

Eddleman LE, Miller PM, Miller RF, Dysart PL. 1994. Western juniper woodlands of the Pacific Northwest — Science Assessment. USDA Forest Service, Interior Columbia Basin Ecosystem Management Project. www.icbemp.gov/science/eddleman.pdf.

Gifford GF. 1970. Some water movement patterns over and through pinyon-juniper litter. Technical notes. J Range Manage 23:365–6.

Gifford GF. 1975. Approximate annual water budgets of two chained pinyon-juniper sites. J Range Manage 28:73–4.

Hawkins RH. 1987. Applied hydrology in the pinyon-juniper type. In: Proc Pinyon-Juniper Conference. Reno, NV. Ore Ag Exp Sta Tech Rep No 7763.

Hibbert RA. 1983. Water yield improvement potential by vegetation management on western rangelands. Water Res Bull 19:375–81.

Hull Jr AC. 1972. Rainfall and snowfall interception by big sagebrush. Abs Papers Proc Utah Acad Sci 49:64–5.

Huxman TE, Wilcox BP, Breshears DD, et al. 2005. Ecohydrological implications of woody plant encroachment. Ecology 86:308–19.

Lane LJ, Barnes FJ. 1987. Water balance calculations in southwestern woodlands. In: Proc Pinyon-Juniper Conference. Reno, NV. Ore Ag Exp Sta Tech Rep No 7763.

Larsen RE. 1993. Interception and water holding capacity of western juniper. Ph.D. dissertation. Oregon State University, Corvallis, OR.

Levy S. 2003. Turbulence in the Klamath River basin. Bioscience 53:315–20.

Miller PM, Kramer S, Eddleman LE. 1990. Allocation patterns of carbon and minerals in juvenile and small-adult *Juniperus occidentalis*. Forest Sci 36:729–42.

Miller RF, Bates JD, Svejcar TJ, et al. 2005. Biology, Ecology, and Management of Western Juniper (*Juniperus occidentalis*). Ag Exp Sta Tech Bull No 152, Oregon State University.

Miller RF, Rose JA. 1995. Historic expansion of *Juniperus occidentalis* (western juniper) in southeastern Oregon. Great Basin Naturalist 55:37–45.

Miller RF, Wigand PE. 1994. Holocene changes in semiarid pinyon-juniper woodlands. Bioscience 44:465–74.

[NOAA] National Oceanic and Atmospheric Administration. 1973. Atlas 2 rainfall depth-duration-frequency maps for the western United States. www.weather.gov/oh/hdsc/currentpf.htm#N2.

Pierson FB, Bates JD, Svejcar TJ, Hardegree SP. 2007. Runoff and erosion after cutting western juniper. Range Ecol Manage 60:285–92.

Skau CM. 1964. Interception, throughfall and stem flow in Utah and alligator juniper cover types of northern Arizona. Forest Sci 10:283–7.

Thurow TL, Hester JW. 1997. How an increase or a reduction in juniper cover alters rangeland hydrology. In: Proc Juniper Symposium, Texas A&M University, San Angelo, TX.

Vaitkus MR, Eddleman LE. 1987. Composition and productivity of a western juniper understory and its response to canopy removal. In: Proc Pinyon-Juniper Conference. Reno, NV. Ore Ag Exp Sta Tech Rep No 7763.

West NE, Gifford GF. 1976. Rainfall interception by cool desert shrubs. J Range Manage 29:171–3.

Wilcox BP. 2002. Shrub control and stream flow on rangelands: A process based viewpoint. J Range Manage 55:318–26.

Young JA, Evans RA, Easi DA. 1984. Stem flow on western juniper (*Juniperus occidentalis*) trees. Weed Sci 32:320–7.

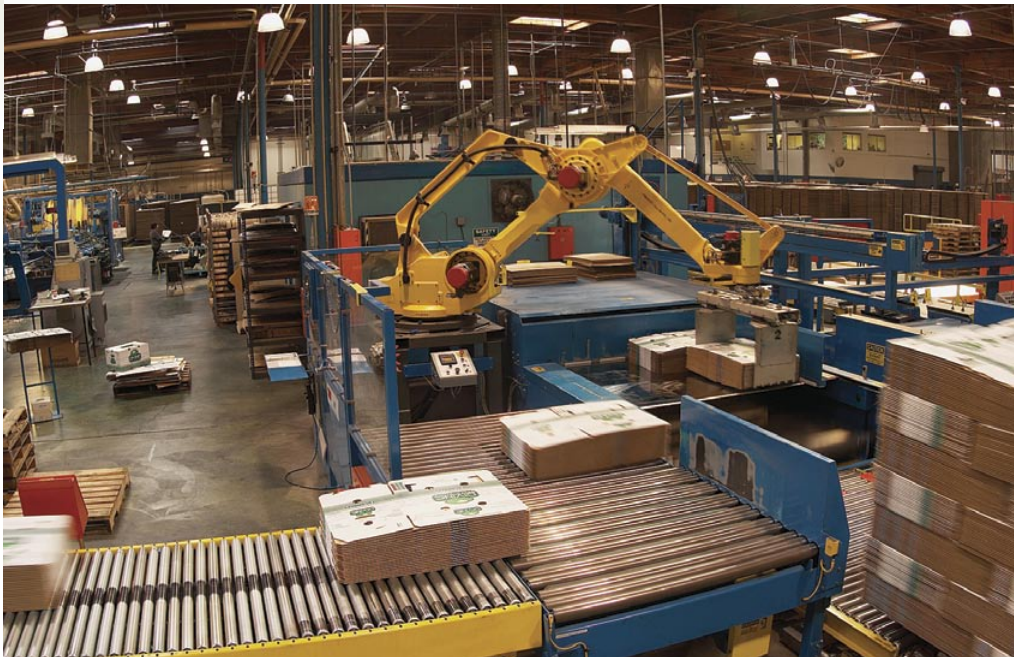
RESEARCH ARTICLE

Most West Coast agricultural cooperatives are financially competitive

by Shermain D. Hardesty *and* Vikas D. Salgia

Agricultural producers and lenders have expressed concerns about the highly publicized financial difficulties experienced by some agricultural cooperatives. This study analyzes the comparative financial performance of cooperatives and investor-owned firms in four sectors: fruits and vegetables, dairy, farm supply and grain. Standard financial ratios measuring profitability, liquidity, leverage and asset efficiency were analyzed for 1991 through 2002. The overall financial performance of cooperatives on the West Coast was on par with that of similar investor-owned firms.

Fruit Growers Supply Company



Agricultural cooperatives were created to benefit member farmers, rather than investors. *Above,* Fruit Growers Supply Company is a 100-year-old cooperative that supplies citrus packinghouses with cartons from its plants in Ontario and Visalia, Calif.

Cooperatives are corporations that are owned and governed by the firms or people who use them; they differ from other businesses because they operate for the benefit of their members, rather than to earn profit for investors. Cooperatives have played an important historical role in promoting the economic welfare of California's agricultural producers. Recently, however, reports regarding the financial difficulties experienced by U.S. agricultural cooperatives have been much more common than news of their successes. In particular, the 2002 bankruptcy of Farmland Industries — a federation of 1,700 independent Midwestern cooperatives and the nation's largest agricultural cooperative — received considerable media attention. In California, news about cooperatives has centered on the bankruptcy of Tri Valley Growers in 2000; the dissolutions of Blue Anchor and the Rice Growers Association of California in 2000; and the conversions of Calavo in 2001 and Diamond Walnut Growers in 2005, to publicly traded, investor-owned corporations.

Such news has raised concerns among producers and lenders regarding the viability of the cooperative form of agricultural business. In the agricultural sector, producers use cooperatives to market and process their crops and livestock, purchase supplies and services, negotiate terms of trade with processors of their raw product, and provide credit for their operations. An international management consulting firm, McKinsey & Company, issued a report in 2002 alleging that agricultural cooperatives "destroy value" because few cooperatives "have changed the way they operate" (Dempsey et al. 2002). This report received considerable attention from the management and boards of numerous large cooperatives, despite the fact that its analysis was based on only 2 years of data. Some cooperative researchers also noted other technical limitations.

Was McKinsey & Company's claim that agricultural cooperatives destroy value justified? Or do cooperatives benefit California's agricultural producers? What is the future for agricultural cooperatives in California?

Economic role of cooperatives

Cooperatives have been part of the agricultural sector in the United States for approximately 200 years. They can benefit their members in several different ways. In the Midwest, cooperatives were formed primarily to maximize the welfare of their individual members. These cooperatives handle the entire output of their members regardless of market needs, and are clearly extensions of their members' farming businesses. Conversely, many of the marketing cooperatives formed in California during the first quarter of the 20th century were designed to create market power by improving product quality and restricting raw product flows. Such market power–oriented cooperatives seek to maximize the profitability of the firm, rather than the welfare of individual members.

These different objectives can have vastly different impacts on the operations of cooperatives. A cooperative with a market-power structure could operate in niche markets with a strong brand identity and handle limited volumes of member product to maximize its profitability as a firm. This type of cooperative would then distribute some or all of its earnings to its members. Some of these cooperatives, such as

Mountain States Lamb, require members to buy enough delivery rights to match their delivery volumes. Members must invest in a delivery right for each lamb they deliver annually to Mountain States Lamb for processing and marketing. The delivery rights control the amount of raw product delivered by members; they depend on the processing capacity of the cooperative's plant. Investment in delivery rights is part of a producer marketing agreement. If a producer is unable to deliver the agreed amount of raw product, purchase of commodities is authorized by the cooperative for undelivered obligations. Such delivery rights are marketable and can appreciate in value if the cooperative is successful. For example, the founding members of Dakota Growers Pasta paid $3.85 in 1991 for a right to deliver a bushel of durum wheat annually to the cooperative. By 1998, the cooperative's strong earnings enabled retiring members to sell a delivery right for $7.50.

In contrast, a Midwestern-style marketing cooperative could maximize benefits to its members by accepting their deliveries up to its break-even point, which would provide as much of a home for their product as possible without incurring losses. While this decreases the members' potential earnings from the cooperative, it also reduces the risk they face.

Comparative financial analysis

Past nationwide studies. It is inappropriate to assume that all cooperatives are seeking to maximize their profitability as firms. Nonetheless, various national studies were conducted during the late 1980s that compared the financial performance of agricultural cooperatives and investor-owned firms (IOFs). The findings from these studies varied widely (Lerman and Parliament 1990; Parliament et al. 1990; Schrader et al. 1985).

These financial performance studies used ratio analysis, including profitability measures. Ratio analysis is a tool used to evaluate a firm's financial performance by taking data from its financial statements and comparing the ratios over time, and/or with those for other firms or the industry. However, Sexton and Iskow (1988) pointed out how analyses of cooperatives based upon financial ratios, although popular, were not based on economic theory. Specifically, they noted that since cooperatives are extensions of their members' businesses, a cooperative could be less profitable than an investor-owned firm and still be beneficial to a member — as long as the member's discounted stream of returns from the cooperative was greater than those from marketing the commodity directly or through an investor-owned firm. For example, membership in an almond marketing cooperative that is averaging a 6% operating margin while one of its investor-owned competitors is averaging a 10% operating margin could still be beneficial to the cooperative's members. Members could receive a higher price for their almonds from the cooperative than if they sold their crop to the investor-owned firm; the investor-owned firm strives to minimize its costs, including the price it pays for its almonds.

That said, critical stakeholders of cooperatives — members, management and lenders — are used to measuring performance; financial ratios provide

Glossary

Asset efficiency: Ability to generate revenue from assets.

Current ratio: Current assets divided by current liabilities; an indicator of liquidity.

Debt-equity ratio: Long-term debt divided by total equity; an indicator of degree of leverage.

Equity: Net worth; total assets less total liabilities.

Investor-owned firm (IOF): A business owned by multiple investors seeking to maximize their returns, as opposed to a sole proprietorship, member-owned cooperative or public agency.

Leverage: Use of debt to finance a firm's assets.

Liquidity: Ability to convert assets into cash in order to meet debt repayment obligations.

Operating margin: Measure of what proportion of a company's revenue is left over after paying for variable costs of production (such as wages and raw materials) to pay its fixed costs (such as interest on debt); a measure of profitability.

Profitability: Ability of a firm to generate net income.

Sunkist Growers

A 12-year economic comparison of cooperatives and investor-owned firms on the West Coast found that fruit and vegetable cooperatives had higher operating margins but also more annual volatility. *Above,* oranges at the Sunkist Growers cooperative, which was formed 114 years ago to market California and Arizona citrus.

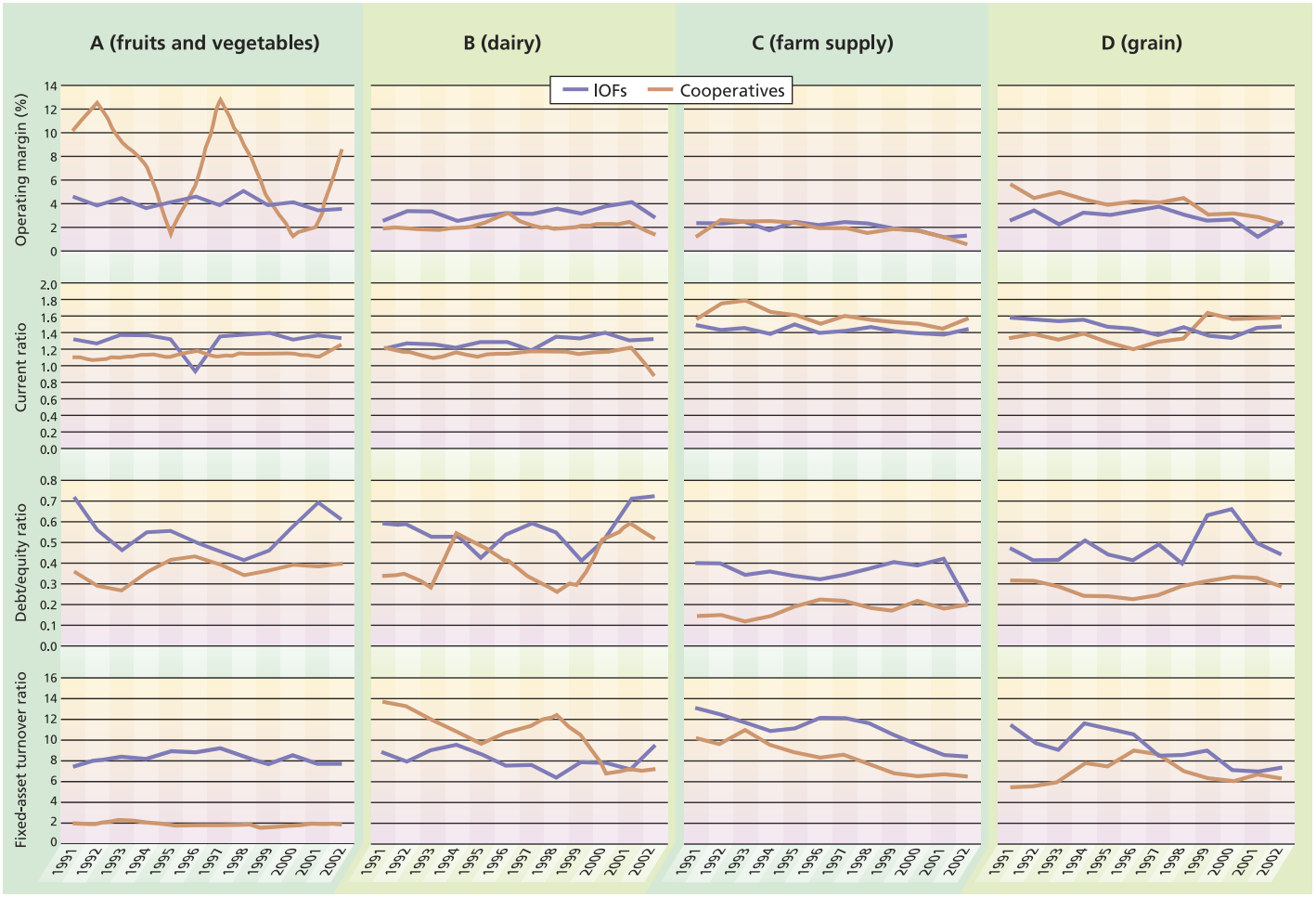


Fig. 1. Comparison of financial ratios for West Coast agricultural cooperatives and U.S. investor-owned firms (IOFs) in (A) fruits and vegetables, (B) dairy, (C) farm supply and (D) grain sectors, for 1991–2002.

the most readily available tool to compare cooperative and investor-owned firms.

Current West Coast study. Given recent concerns expressed about the viability of cooperatives, we compared the financial performance of agricultural cooperatives and investor-owned firms in similar sectors, and of comparable size as measured by total assets. The sample was 41 cooperatives in four West Coast sectors: 11 from fruits and vegetables, 5 from dairy, 14 from farm supply and 11 from grain. Due to the small number of cooperatives in some California sectors, the analysis was expanded to include Oregon and Washington to protect confidentiality.

The specific financial ratios analyzed are indicators of profitability, liquidity, leverage and asset efficiency (see glossary; table 1). Annual financial ratios were calculated for each sector by aggregating data for the 1991 to 2002 study period. Data from the financial statements of the 41 cooperatives was provided by CoBank, the largest lender to agricultural cooperatives in the United States. Aggregated financial data for the investor-owned firms was obtained from various issues of the Risk Management Association publication *Annual Statement Studies* (RMA 1991–2001). Over the time period covered by the study, the number of investor-owned firms included in the RMA reports ranged by sector from: 27 to 268 for fruits and vegetables, 20 to 162 for dairy, 297 to 1,024 for farm supply, and 28 to 291 for grain.

Average financial ratios

There was considerable variation between sectors in the averages for the ratios studied (table 2). Except for grain, there were no consistent results for the three profitability measures. For example, the fruits and vegetable cooperatives had higher average operating margins but lower average rates of return on assets and equity than their investor-owned-firm counterparts.

The average liquidity of dairy cooperatives was lower, but their average leverage was also lower and their asset efficiency was higher than those for their investor-owned-firm counterparts. There were similarly mixed results in the farm supply and fruits and vegetables sectors. The grain cooperatives had higher averages than the investor-owned firms for all three profitability measures, but the averages were mixed for other ratios. The most consistent result was that, in all four sectors, cooperatives averaged lower levels of leverage than their investor-owned-firm counterparts.

Performance trends

Based solely on visual observations, we compared trends in the financial

ratios of cooperatives and their investor-owned-firm counterparts. For each sector, we reviewed trends in four financial indicators: the operating margin (one of the three profitability measures), as well as liquidity, leverage and asset utilization. A more rigorous analysis is presented in a detailed research paper, which is available from the lead author (http://hardesty.ucdavis.edu).

Fruits and vegetables. Some of the fruit and vegetable cooperatives and investor-owned firms included in this study market only fresh produce, while the others are involved in drying, canning and/or freezing. Compared to the investor-owned firms, the cooperatives had a higher average operating margin, but with greater volatility from year to year (fig. 1A). Similarly, the rates of return for cooperatives on equity and assets were cyclical. The fruit and vegetable cooperatives also had less liquidity, averaging 0.2 points less than the investor-owned firms for the current ratio. However, the fact that the cooperatives averaged $0.20 less in current assets than their investor-owned counterparts to cover each dollar of their current liabilities was counteracted by the cooperatives' lower use of debt. The most noticeable difference was that the investor-owned firms had significantly higher asset utilization, generating an average of $6 more in sales per dollar of fixed assets than the cooperatives.

Dairy. The dairy cooperatives and investor-owned firms process fluid milk into cheese, butter and other dairy products. Overall, the financial performances of cooperatives and investor-owned firms in dairy were comparable (fig. 1B). The investor-owned firms had better margins on operations and maintained higher liquidity than cooperatives during the entire study period. On the other hand, the dairy cooperatives were less leveraged than the investor-owned firms and had higher rates of asset utilization until the final 3 years of the 12-year study period.

Farm supply. The farm supply cooperatives and investor-owned firms primarily sell seed, packing materials, fertilizer and equipment. Again, the overall financial performances of the two types of firms in the farm supply sector were comparable (fig. 1C). The operating margins of the two types of firms were very stable and similar throughout the 12-year study period. These cooperatives had higher liquidity, but this advantage diminished over time. Farm supply cooperatives consistently had less leverage than their investor-owned-firm counterparts. However, their asset efficiency rates were also consistently lower than those of the investor-owned firms.

Grain. The grain cooperatives and investor-owned firms are mainly engaged in storage and milling. The overall financial performance of the two types of firms was comparable over time (fig. 1D). The cooperatives had higher, but declining, operating margins than the investor-owned firms. While the investor-owned firms initially had higher liquidity, this situation reversed itself in the late 1990s. As in the other sectors, grain cooperatives carried lower levels of leverage than their investor-owned-firm counterparts. The advantage of investor-owned grain firms with regard to asset efficiency has diminished.

TABLE 1. Financial ratios analyzed

Ratio	Performance indicator	Definition
Return on equity (ROE)	Profitability	Income*/equity (%)
Return on assets (ROA)	Profitability	Income*/total assets (%)
Operating margin (OM)	Profitability	Operating profit/net sales (%)
Current ratio (CR)	Liquidity	Current assets/current liabilities
Debt-equity ratio (D/E)	Leverage	Noncurrent liabilities/equity
Fixed asset turnover ratio (FATR)	Asset efficiency	Net sales/fixed assets

* Adjustment for Income: income = income tax + tax payable + net income.

TABLE 2. Average financial ratios by sector and firm type (cooperatives and investor-owned firms), 1991–2002

	Fruits & vegetables		Dairy		Farm supply		Grain	
Ratio*	IOFs	Coops	IOFs	Coops	IOFs	Coops	IOFs	Coops
ROE (%)	16.6	14.2	20.0	26.7	13.3	11.1	14.3	18.2
ROA (%)	5.9	5.0	7.6	7.4	5.2	5.9	5.9	8.5
OM (%)	4.1	6.9	3.2	2.1	2.0	1.8	2.8	3.8
CR	1.3	1.1	1.3	1.1	1.4	1.6	1.5	1.4
D/E	0.6	0.4	0.6	0.4	0.4	0.2	0.5	0.3
FATR	8.2	1.8	8.2	10.4	11.1	8.2	9.3	6.8

* See table 1 for definitions.

These findings should alleviate the concerns expressed by producers and lenders regarding the viability of agricultural cooperatives.

Performance is comparable

Contrary to popular belief, we found that the overall financial performance of cooperatives was on par with that of similar investor-owned firms. The only consistent difference regarding profitability was that all three of the profitability ratios of grain cooperatives were higher than those of their investor-owned-firm counterparts; however, the relative advantage of grain cooperatives has been declining over time. Although fruit and vegetable cooperatives averaged higher profitability levels than the investor-owned firms, their profitability was noticeably cyclical. Liquidity levels were relatively stable, and differences between the two types of firms were small during the 12-year study period.

Cooperatives in all sectors had lower debt/equity ratios than their investor-owned-firm counterparts. This finding is surprising for several reasons: (1) cooperatives have access to fewer sources of equity capital than investor-owned firms, (2) members want to maximize cash payments from their cooperatives, and (3) members do not value the eq-

uity they have within cooperatives. The lower leverage levels of cooperatives warrant further research.

The fact that cooperatives had lower asset efficiency than their investor-owned-firm counterparts in three of the four sectors evaluated (grain, fruits and vegetables, and farm supply) appears problematic initially. However, this result is consistent with the economic role of cooperatives: many are expected to provide a home for their members' product and need to maintain excess capacity. It is not surprising that this hypothesis did not hold for dairy cooperatives, since dairy producers tend to have consistent production volumes and market their production through only one source, thus reducing their cooperative's need for excess capacity.

Among the four sectors included in this analysis, only the fruit and vegetable cooperatives displayed general weakness. Cooperatives in general have a tendency to market a high proportion of undifferentiated, low-value-added products (Sexton and Iskow 1988). Clearly, this tendency could explain both the sharply lower asset-utilization rates and cyclical profitability of fruit and vegetable cooperatives. If the investor-owned firms market a higher proportion of value-added products, they are more likely to maintain year-round utilization of their processing equipment and to have returns that are less susceptible to the highly competitive international market for undifferentiated canned fruits and vegetables.

Although Hariyoga and Sexton (2004) concluded that the cooperative structure of Tri Valley Growers was not a major factor in its bankruptcy, this sector warrants further analysis. Given the declining business volumes and membership levels of all cooperatives, their long-term viability may depend on their ability to reduce costs substantially as processors of undifferentiated products or to enhance their capabilities as marketers of value-added products.

With the exception of the fruit and vegetable sector, this study found that the overall financial performance of agricultural cooperatives on the West Coast has been comparable to that of investor-owned firms over the 12-year study period. These findings should alleviate the concerns expressed by producers and lenders regarding the viability of most agricultural cooperatives.

Furthermore, use of the cooperative structure in California's agricultural sector continues to evolve. Earlier this year, tomato growers in California formed a cooperative to gain market power by improving quality and food safety standards. Its members are required to pass field and packinghouse audits and are expected to adopt a comprehensive set of good agricultural practices regarding pesticide use as well as fair treatment of farm and packinghouse workers. Orange marketers recently created a marketing agency in common called the California Citrus Growers Association. The objective of this "cooperative of cooperatives" is to voluntarily control product flows and restore the market power lost by producers when the federal marketing order was eliminated. Meanwhile, cooperative bargaining associations are branching out and collaborating with their bargaining partners to fund research and marketing programs to strengthen markets for their members' products (see page 177). These recent developments, along with this review of how cooperatives perform financially, clearly indicate that cooperatives continue to promote the economic welfare of agricultural producers on the West Coast.

Blue Diamond

In general, the overall financial performance of agricultural cooperatives was similar to that of investor-owned firms, indicating that this is still a viable business model. *Above,* Sacramento-based Blue Diamond is owned by about 3,000 growers and is the world's largest tree-nut marketer and processor.

S.D. Hardesty is Cooperative Extension Specialist, and V.D. Salgia was Postgraduate Researcher, Department of Agricultural and Resource Economics, UC Davis. *This research was partially supported by a USDA Rural Cooperative Development grant.*

References

Dempsey JJ, Kumar AA, Loyd B, Merkel LS. 2002. A value culture for agriculture. McKinsey Quarterly:3.

Hariyoga H, Sexton RJ. 2004. The bankruptcy of Tri Valley Growers: What went wrong and what can we learn from it? Ag Resource Econ Update 7 (July/August):6.

Lerman Z, Parliament C. 1990. Comparative performance of cooperatives and investor-owned firms in U.S. food industries. Agribusiness 6(6):527–40.

Parliament C, Lerman Z, Fulton J. 1990. Performance of cooperatives and investor-owned firms in the dairy industry. J Ag Cooperation 5:1–16.

[RMA] Risk Management Association. 1991–2001. *Annual Statement Studies, Financial Ratio Benchmarks*. www.rmahq.org/RMA/RMAUniverse/ProductsandServices/RMABookstore/StatementStudies/default.htm.

Schrader LF, Babb EM, Boynton RD, Lang MG. 1985. Cooperative and Proprietary Agribusiness: Comparison of Performance. Purdue Univ Res Bull 982.

Sexton R J, Iskow J. 1988. Factors Critical to the Success or Failure of Emerging Agricultural Cooperatives. Giannini Foundation Info Series 88-3, 52 p. http://giannini.ucop.edu/InfoSeries/883-Coops.pdf.

California farmers adapt mandated marketing programs to the 21st century

by Hoy Carman

Mandated marketing programs are an important component of California agriculture. The state's 63 marketing programs cover commodities that accounted for two-thirds of the total value of California agricultural output in 2004. California farmers have recently paid annual assessments totaling more than $226 million to support advertising, promotion, research and inspection programs. Marketing programs have evolved from emphasizing supply controls in the 1930s and 1940s to the current focus on generic advertising and promotion, food safety inspection, health and nutrition research, and market information.

Buy California Marketing Agreement/"California Grown"

About two-thirds of California crops fall under marketing orders, in which growers pay mandatory assessments for marketing, promotion, research and quality inspection. *Above,* the Buy California Marketing Agreement advertises the state's crops as "California Grown"; it is supported by state and industry funds.

California's government-mandated marketing programs covered commodities accounting for over $21.18 billion (66%) of California crop and livestock production in 2004. While the framework for these marketing programs is set by legislation, the specific provisions are proposed by producers, approved by the secretary of agriculture (marketing orders and agreements) or the legislature and governor (commissions and councils), and enacted by a supermajority vote of producers covered by the program's provisions.

Once enacted, all producers are subject to program provisions and all must pay assessments to cover program costs, with enforcement based on the police and taxing powers of government. This paper reviews the nature, importance, extent and changing use of common program provisions for mandated marketing programs utilized by California producers, and the development of new research, promotion and information initiatives. Not included in the data tables are California producers' participation in federal promotion programs, commonly referred to as national check-off programs, nor activities of the California Department of Food and Agriculture's (CDFA) Dairy Branch in administering and enforcing provisions of the California Milk Marketing Order.

Mandated marketing programs

In 2004, mandated marketing programs covered California commodities ranging from 96.6% of the value of fruit and nut production to 8.3% of nursery and floral production (table 1). As of June 2006, California's 63 active marketing programs included 11 federal marketing orders, 29 state marketing orders and agreements, 20 commissions, and 3 councils (see sidebar, page 178). Since then the Pistachio Commission has been terminated by an industry vote, and a California Leafy Green Products Handler Marketing Agreement has been approved to certify the safe handling, shipment and sale of leafy green products to consumers (CDFA 2007). Individual commodity marketing programs have been terminated, consolidated and initiated in response to changing marketing issues, with the total number increasing over time. Notable

TABLE 1. Production value for California commodities covered by marketing programs as share of all commodities in each crop category, 2004

Crop category*	Total production value	Production value under marketing programs	Value covered by marketing programs
	..... *$1,000s*		%
Field crops	3,564,602	572,276	16.1
Fruits and nuts	9,562,944	9,234,237	96.6
Vegetables	7,200,499	4,004,276	55.6
Animal products	8,623,140	7,067,058	81.9
Nursery and floral	3,659,297	303,562	8.3
Total	31,835,185	21,181,409	66.5

* Fishery and forestry are excluded.
Source: USDA-NASS 2005.

Mandated marketing programs supported by California producers

Federal marketing orders for fruits, vegetables, nuts and specialty crops are authorized by the Agricultural Marketing Agreement Act of 1937, as amended. They are requested by producers to help solve marketing problems and can cover production in one or several states. A marketing order may contain provisions for one or more of the following: generic advertising and sales promotion; production, processing and marketing research; quality regulations with inspection; supply management or volume control; the standardization of containers or packs; and the prohibition of unfair trade practices. The secretary of agriculture holds public hearings on the proposed marketing order, and if it is determined to be in the public interest and likely to help solve the industry's marketing problems, it goes to a producer referendum. Two-thirds of the producers, or producers representing two-thirds of the volume produced in the proposed marketing order area, must vote to adopt the order. Once passed, an order is binding on all producers.

California marketing orders are authorized by the California Agricultural Marketing Act of 1937. They are available for a wider range of commodities and allow for more activities than federal orders. California legislation permits programs for advertising and promotion, research, the prohibition of unfair trade practices, product inspection, stabilization pools and the regulation of grades and standards. Procedures for establishing a state order are similar to a federal order, but the voting requirements differ: they must be approved by (1) 51% of the producers marketing 65% of the volume; (2) 65% of the producers marketing 51% of the volume; or (3) a minimum of 40% of producers voting, then of those voting 51% of the voting producers with 65% of the volume, or vice-versa. An order is binding on all producers.

California marketing agreements are authorized by the California Agricultural Marketing Act of 1937, with provisions similar to California marketing orders. There is no vote on a marketing agreement, since it is a signed contract between the secretary of agriculture and individual handlers of a particular commodity. Agreements are voluntary and affect only the handlers who sign.

California commodity commissions and councils are each established by a specific law passed by the state legislature and signed by the governor. While the provisions for each commission are wide open, most concentrate on advertising, promotion and research; councils tend to concentrate on education programs, promotion and research. The establishment of a commission typically requires an industry referendum, and the voting requirements are usually the same as for a marketing order. Councils have been established without an industry vote. California commodity commissions and councils have more program and budget autonomy than do marketing orders. They develop their own operating plans and budgets, with CDFA concurrence, and can hire executives and elect commission members without the CDFA's prior approval.

National check-off programs are federal programs to fund generic advertising and research activities for a particular commodity that are financed by mandatory assessments on all of the domestically marketed commodity. The name "check-off" comes from the method of collecting assessments. Producers, handlers and/or importers are required to pay an assessment, usually deducted from revenue at the time of sale. Prior to 1996, national check-off programs required that Congress pass specific legislation for each individual commodity; this procedure is still available. Then passage of the Commodity Promotion, Research, and Information Act of 1996 gave USDA broad-based authority to establish national generic promotion and research programs for nearly all commodities, either at its own initiative or upon the request of an industry group. There are currently 17 of these programs with estimated 2005 assessments of $765 million.

trends have been a decrease in the number of federal marketing orders applicable to California crops and an increase in the number of commodity commissions.

More than half of these programs have been established since 1980. In addition, 12 commodity commissions have been established since 1990, with several replacing marketing orders. While all mandated marketing programs are subject to government approval and oversight, commissions and councils tend to enjoy the most autonomy.

Mandated marketing programs can include one or more provisions for research, minimum quality standards, regulation of packaging and containers, quantity controls, and/or generic advertising and promotion. Generic, as contrasted with brand advertising and promotion, speaks to general commodity characteristics rather than referring to a specific producer, brand name or processor. The purpose of generic programs is to increase the total demand for a commodity (the size of the pie), while brand programs seek to increase market share (the slice of the pie). Federal and state marketing orders established during the 1930s and 1940s emphasized the use of supply controls to improve prices. Now the provisions that are most often used by federal programs are minimum grades and sizes, pack and container regulations, research and generic promotion. Likewise, the emphasis of state marketing orders has shifted, with more than three-quarters of California programs including provisions for generic promotion and research by 1960. In addition, California commodity commissions emphasizing promotion and research have taken the place of many state marketing orders.

Commodity promotion litigation

While producer support for promotion programs is strong, it is not unanimous, and litigation over mandatory assessments for advertising and promotion has been essentially continuous since the 1980s. The majority of lawsuits have been filed by large growers for various reasons, including philosophical opposition to government interference in marketing their products, a belief that they could obtain a better return promoting their own brand, and basic disagreements with the promotion message or operation of the program.

Three cases concerning the constitutionality of generic promotion programs

In 2004, mandated marketing programs covered California commodities ranging from 96.6% of fruits and nuts to 8.3% of nursery and floral production.

have been heard by the U.S. Supreme Court (Kaiser et al. 2005, ch. 3). In the 1997 case of *Glickman v. Wileman Bros. & Elliott, Inc., et al.*, the Supreme Court ruled that federally mandated generic advertising for California peaches, plums and nectarines did not violate the First Amendment of the U.S. Constitution. In the five-to-four ruling, the Court noted that the business entities that are compelled to fund generic advertising do so as part of a broader collective enterprise in which the freedom to act independently is already constrained by the regulatory scheme.

This ruling seemed to take much of the legal pressure off generic promotion programs, until a contrary decision was issued in 2001. In *U.S. v. United Foods,* the Supreme Court ruled that the national Mushroom Promotion Act of 1990 violated the First Amendment. This ruling set off a flood of litigation against other promotion programs, with lower courts striking down a number of them.

Then, in 2005 the Supreme Court agreed to hear a third promotion program case on an Eighth Circuit Court ruling that the national beef check-off program was unconstitutional. In *Livestock Marketing Association v. USDA*, the Supreme Court ruled (May 23, 2005) that the national beef check-off program is constitutional. The ruling, which overturned lower court decisions, stated that the beef promotion messages were government speech that is not subject to certain First Amendment challenges. This newest ruling is expected to settle pending litigation for several generic promotion programs and increase producer interest in promotional programs. Issues still remain; for example, in 2005 Paramount Farms, California's largest pistachio producer, filed a lawsuit against the California Pistachio Commission charging that its generic promotion program is ineffective. Then in 2007, the California Pistachio Commission was terminated by a referendum vote of the growers.

Program expenditures increasing

Budgeted expenditures for California marketing programs have increased significantly over time. Lee et al. (1996) estimated total budgets of $71.35 million in 1985 and $112.94 million in 1992. The estimated total for 2002–2003 was just over $208 million (Kaiser et al. 2005, ch. 2), increasing to over $226 million for 2004–2005 (table 2C). A number of factors have contributed to the observed increase, including participation by more crops (especially vegetables), the effects of inflation, and growth in the importance of individual crops.

Tables 2A, 2B and 2C provide details on California mandated marketing programs and expenditures in the broad categories of administration, promotion, inspection and research. These are the most recent budget data available, covering annual budget periods that include months in 2004 in the case of federal marketing orders, to fiscal years that begin in 2005 and early 2006 for some state programs. Note that most programs include only the direct costs attributable to promotion, inspection or research in each of these three categories, with all other expenses (including unallocated overhead) in the administration cost category.

Overall, the 63 California programs allocated 68.1% of their total budgets for advertising and promotion, 11.0% for research, 3.9% for inspection programs and the remainder for administration. California marketing orders and agreements accounted for 44.6% of total expenditures, followed by state commodity commissions (33.3%), federal marketing orders (18.3%) and councils (3.8%).

Advertising and promotion. California commodity producer groups spent over $154 million on generic advertising and promotion programs during 2004–2005 (table 2B). These programs ranged from high-profile TV advertising such as "Real California Cheese" and "Got Milk?" to more common media messages in magazines, newspapers, radio and billboards, and public relations campaigns.

Research has documented significant increases in product demand and prices as a result of commodity advertising and promotion programs, with the net monetary benefits to producers being much greater than costs (Kaiser et al. 2005). For example, promotions led to statistically significant increases in demand and price in case studies for eight California crops (table grapes, eggs, prunes, avocados, almonds, walnuts, raisins and strawberries) and benefit-cost estimates for four national check-off programs (dairy, beef, pork and cotton). Kaiser et al. (2005, p. 412) wrote that "the overwhelming conclusion . . . is that mandated commodity marketing programs have been very profitable for California's agricultural producers. In every case, the evidence suggests that one can be reasonably confident that the benefits have well exceeded the costs and that it would

TABLE 2A. Federal marketing orders for California commodities, budgeted expenditures by category, 2004–2005

Federal marketing order	Administration	Promotion	Inspection	Research	Budgeted total
			$		
Almonds	5,550,023	16,330,000		2,147,321	24,027,344
Dates	110,501	112,499			223,000
Grapes–California desert	88,091			100,000	188,091
Kiwifruit	88,859				88,859
Nectarines	638,770	3,161,852	1,153,676	208,568	5,162,866
Olives	360,563	633,500		275,000	1,269,063
Peaches (fresh)	540,455	3,188,457	1,240,520	208,570	5,178,002
Pistachios	271,499				271,499
Plums (dried)	275,800				275,800
Raisins	2,200,000				2,200,000
Walnuts	712,000	1,393,500		644,000	2,749,500
Subtotal	10,836,561	24,819,808	2,394,196	3,583,459	41,634,024

Source: Provided in private correspondence by USDA Agricultural Marketing Service, Fresno Office, and USDA-AMS 2007.

TABLE 2B. State marketing orders and agreements for California commodities, budgeted expenditures by category, 2004–2005

California marketing order	Administration	Promotion	Inspection	Research	Budgeted total
			$		
Alfalfa seed production	25,620			28,430	54,050
Artichoke promotion	54,000	3,800		240,000	297,800
Buy California Market. Agree.		522,500			
Cantaloupe	70,240	33,500	149,434		253,174
Carrots (fresh)	84,900	148,000		375,000	607,900
Celery	63,950			207,717	271,667
Cherry	263,900	1,731,018		129,731	2,124,649
Citrus nursery	75,000			95,000	170,000
Citrus research	708,300			3,280,147	3,988,447
Dry beans	129,050	130,500	0	135,250	394,800
Figs (dried)	478,558	427,929	0	116,902	1,023,389
Garlic and onion dehydrator	211,636		229,272		440,908
Garlic and onion research	93,900			100,000	193,900
Iceberg lettuce research	278,051	0		550,750	828,801
Melon research	61,970			165,954	227,924
Manufacturing milk	98,500	1,307,500		0	1,406,000
Market milk	2,093,000	35,692,000		3,340,000	41,125,000
Milk (fluid)	885,000	19,170,324			20,055,324
Peaches (cling)	158,800	1,620,000		280,000	2,058,800
Pears	215,404	1,334,593		187,746	1,737,743
Plums	736,955	1,546,283	800,715	111,718	3,195,671
Plums (dried)	790,065	3,685,000		438,000	4,913,065
Potato research	53,150			57,000	110,150
Raisins	1,222,000	4,479,500		607,000	6,308,500
Rice research	192,500			2,416,361	2,608,861
Strawberry (processing)	438,300		481,800		920,100
Tomato (processing)	180,000		3,540,204	40,000	3,760,204
Wild rice	27,660	56,805		20,299	104,764
Winegrape insp. agreement	103,500		1,199,723	135,000	1,438,223
Subtotal	10,316,409	71,366,752	6,401,148	13,058,005	101,142,314

TABLE 2C. California commodity commissions and councils, budgeted expenditures, 2004–2005

Commissions	Administration	Promotion	Inspection	Research	Budgeted total
			$		
Apple	335,175	178,500		41,500	555,175
Asparagus	161,200	492,746		122,476	776,422
Avocado	4,418,500	12,984,200		2,072,500	19,475,200
Date	28,189	0		18,653	46,842
Flower (cut)	191,009	939,865		115,118	1,245,992
Forest products	203,671	1,401,396			1,605,067
Grape rootstock	58,217			184,625	242,842
Grape–table	3,155,000	10,241,871		657,289	14,054,160
Kiwifruit	154,480	215,008		30,900	400,388
Pepper	62,310			132,750	195,060
Pistachio	1,678,145	5,764,362		615,000	8,057,507
Rice	2,664,585	795,500		130,000	3,590,085
Sea urchin	110,000				110,000
Sheep	72,700	89,875		19,844	182,419
Strawberry (fresh)	1,242,128	5,935,621		2,269,672	9,447,421
Tomato	532,790	1,415,790		417,027	2,365,607
Walnut	802,500	9,247,500		990,000	11,040,000
Wheat	313,737	155,500		186,889	656,126
Winegrape, Lake County	64,655	148,022		54,565	267,242
Winegrape, Lodi-Woodbridge	224,176	674,350		185,119	1,083,645
Subtotal	16,473,167	50,680,106		8,243,927	75,397,200
Beef council	636,100	1,344,500		0	1,980,600
Dairy council	560,224	5,672,103		155,500	6,387,827
Salmon council	61,400	121,135		0	182,535
Subtotal	1,257,724	7,137,738		155,500	8,550,962
Total: Tables 2A + 2B + 2C	**38,883,861**	**154,004,404**	**8,795,344**	**25,040,891**	**226,724,500**

Source: Tables 2B, 2C provided in private correspondence with CDFA Division of Marketing Services.

have been profitable for producers to have increased expenditures on the programs."

Tables 2A, 2B and 2C do not include all funding for California commodity promotion or assessments paid by California producers. For example, USDA's Market Access Program awarded $23.95 million (out of total grants of $140 million nationwide) to California trade organizations and marketing programs in 2005. These federal dollar-for-dollar matching funds are used for market development activities in export markets. California producers also contribute to the majority of the 17 national check-off promotion programs, including those for blueberries, beef, cotton, dairy, eggs, fluid milk, honey, lamb, mushrooms, pork, potatoes and watermelons. None of the assessments for national check-off programs, which totaled an estimated $765 million for all U.S. producers for 2005 (Becker 2007), are included in tables 2A and 2B.

Research. There were 28 California programs with research expenditures totaling almost $8.5 million in 1992 (Lee et al. 1996, p. 26); this increased to 45 programs with expenditures of over $21.2 million in 2003–2004 (Kaiser et al. 2005, ch. 2), and further to 48 programs with expenditures over $25 million in 2004–2005 (tables 2A and 2B). The share of total program expenditures dedicated to research increased from about 7.5% in 1992 to about 11% in 2004–2005.

Historically, research funded by California marketing programs was focused on production problems and issues. A sampling of research topics includes new variety development, insect and pest management, irrigation and water management, disease control, pollination, harvest methods/machinery, crop management and postharvest quality control. More recently, California marketing programs have also funded nutrition and health research.

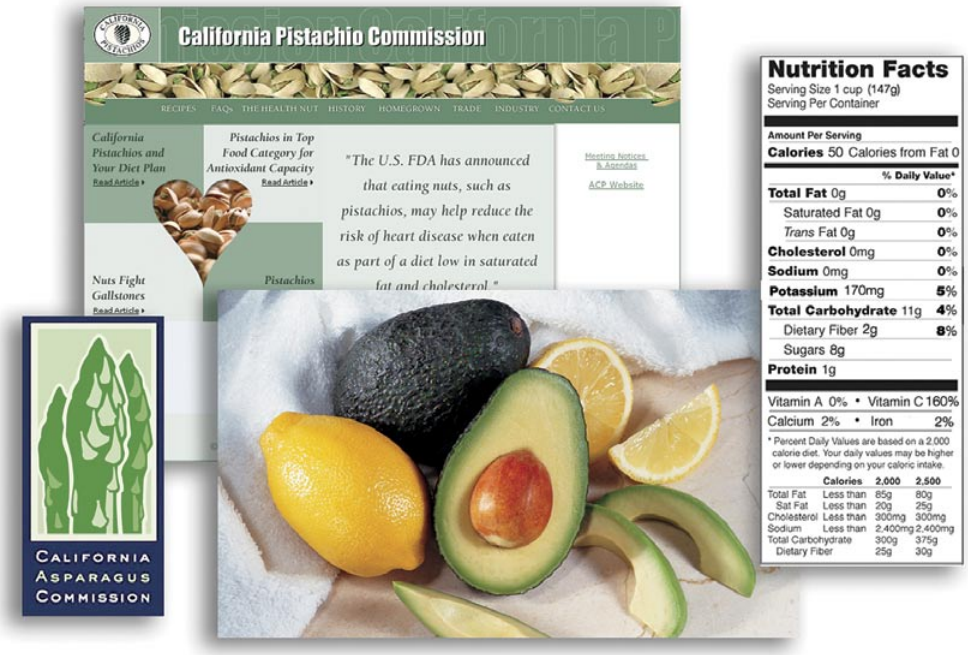
There are numerous examples of the benefits to producers from research expenditures by mandated marketing programs. Research has resulted in cost savings from the reduced use of inputs (water, pesticides and fertilizer) and changes in the input mix, yield increases, reductions in postharvest losses, improved crop characteristics and new management techniques.

Several California commodity groups have funded research at UC that has helped them become the most efficient producers in the United States and world. Included are almonds, walnuts, pistachios, strawberries, lettuce and grapes (Alston and Zilberman 1998). California producers have gained a short- to intermediate-term competitive edge from these research-enabling improvements and, over time, benefits have flowed to consumers in the form of increased supply and availability, improved quality and lower prices.

Minimum quality standards. The purpose of minimum quality standards is to maintain or enhance demand for a commodity by keeping inferior products off the market. They are used to prevent a market failure known as the "lemons" problem, which occurs when a product has unobservable characteristics for which the seller has much better information than the buyer. The best example is early-season sales of immature fruit, which can look good but taste sour. While the individual producer obtains a high price for this fruit, consumer dissatisfaction can adversely affect prices and subsequent sales of high-quality product by other producers later in the season.

Provisions for grades and minimum quality standards are included in all 11 current federal marketing orders for California fruits, vegetables and nuts. However, only 11 of the 29 California state marketing orders and agreements include quality standards and inspection provisions, and just seven of them actively use the provisions. Minimum quality standards typically include a minimum size, to keep small product off the market. Depending on the commodity, they may also specify minimum sweetness (kiwifruit), a minimum degree of maturity (nectarines and peaches), acceptable color and/or amount of discoloration, shape, amount of insect damage or cosmetic defects allowable, and maximum mechanical damage such as bruises, cuts or missing stems.

While empirical analyses of the economic impact of such standards are limited, those available indicate that it is probably relatively small (GAO 1985). However, some minimum quality standards have been controversial, with



In California, some marketing programs have begun promoting the health benefits of crops such as pistachios and avocados, or providing nutrition facts (strawberries) and recipes (asparagus).

charges that they: (1) are an inefficient form of supply control because they divert product to nonfood uses such as animal feed; (2) are *de facto* price discrimination because they divert product to the less-price-sensitive processing market outlet; (3) waste edible fruit with the primary impact being on the poorest consumers; and (4) are sometimes inequitable because of regional variations in production conditions.

Supply controls. A group that controls all or most production of a commodity can gain a measure of monopoly power and enhance short-run returns through restricting the supply placed on the market or practicing price discrimination between markets. However, such monopoly pricing reduces consumer welfare by increasing prices for a smaller amount of product and distorts resource allocation decisions, while producers face all of the problems of maintaining a cartel.

A key feature of marketing orders is that volume controls apply only to the quantity placed on the market — they do not control the amount of product produced. Thus, reduced risk from price stabilization and improved average returns from effective price discrimination can be expected to shift the long-run supply curve to the right, increasing production of the marketing order commodity and increasing required product diversions. Over time, producers discover that they are subject to onerous controls and that returns are no better than before the program.

The use of quantity (supply) control provisions has decreased significantly over time as longer-run economic impacts and administrative problems became evident. Six federal marketing orders for California commodities and two state marketing orders have quantity control provisions but, among these eight, only the federal marketing order for raisins has used these provisions during the last 5 years. In addition, government approval of a new marketing program with supply control provisions is now difficult to obtain.

Food safety efforts

Assuring food safety is the newest use of minimum quality standards and inspection in marketing programs. The purpose of these standards is to enhance product demand by reducing the chances of a food safety incident, thereby increasing consumer confidence and preventing the costs of product recall or rejection. There are three California marketing programs currently stressing food safety: the Leafy Greens Products Handler Marketing Agreement, and the federal marketing orders for pistachios and almonds.

The main provisions of the federal marketing order for pistachios set standards and require testing for quality and aflatoxin, a cancer-causing mold that can contaminate many nuts and

grains. Producers' concerns about the possible negative effects of an aflatoxin poisoning event were the major factor leading to the creation and adoption of the marketing order for pistachios, with support by more than 90% of the growers in a 2004 vote (Gray et al. 2005).

Similarly, the California almond industry is currently developing treatment standards and plans for the pasteurization of all raw, natural almonds as a result of two similar food safety events. In 2001, a *Salmonella* outbreak in Canada was traced back to raw almonds from three orchards in California. Then in spring 2004, foodborne illnesses in Oregon from *Salmonella* were traced to raw almonds purchased from a retailer who obtained all supplies from one handler. The handler initiated a voluntary recall that involved approximately 15 million pounds of almonds.

The California almond industry determined that additional steps were required to ensure that a third such incident does not occur. In summer 2004, the Almond Board of California's board of directors unanimously approved an action plan calling for the pasteurization of 100% raw, natural almonds entering the food distribution system. The proposed new quality standard submitted to USDA will be effective when it has been determined that pasteurization technologies and capacity are sufficient to process all California production. The almond board's target dates for voluntary implementation are during the 2006–2007 production/marketing year, with mandatory implementation for all North American shipments on Aug. 1, 2007, and mandatory implementation for 100% of almond shipments, including exports, on Aug. 1, 2008.

Health and nutrition research

Several California commodity groups are funding health and nutrition research on their products and using promotion programs to disseminate the results. During the last 5 years, more than $8.1 million was spent on research concerning the health and nutrition benefits of almonds, avocados, strawberries and walnuts; these four commodity groups also spent more than $19 million during the 2004–2005 marketing year on promotion using nutrition/health messages. Other commodity groups funding such programs include apples, blueberries, cranberries, kiwifruit, milk and table grapes.

In 1990, the California Walnut Commission became the first California-mandated marketing program to specifically fund health and nutrition research, when it contracted with Loma Linda University for research on the protective effects of walnut consumption on the risk of coronary heart disease. The motivation for walnut nutrition research was to counter the popular perception that walnut consumption was unhealthy because of their high oil content. Likewise, the Almond Board of California initiated a Nutrition Research Program and established a Nutrition Subcommittee in 1995. In 1997, the California Avocado Commission made a strategic change to proactively communicate the nutritional benefits of avocados through national public relations and outreach efforts. In 2003, the California Strawberry Commission began funding nutrition research proposals. This research has already yielded results that are being used in strawberry advertising and promotion.

These four commodities each have developed analyses detailing their chemical and nutritional composition, including the amount and type of fat, calories, vitamins, phytochemicals, antioxidants and minerals. The presence of particular components, already associated with favorable health outcomes, has helped focus research on important health topics. Each commodity group has or is seeking evidence that consuming their product may reduce the risk of heart disease and all have evidence that product components may help to lower the risk of certain cancers. In addition, each of the commodities contains antioxidants known to slow the aging process and protect against heart disease and various forms of cancer. Almonds, avocados and walnuts can be a component of diets to control weight gain and each can be part of a healthy diet for managing and controlling diabetes (see www.almondsarein.com and www.walnuts.org/health/professionals/index.php).

The walnut industry submitted its research results for a heart health claim to the U.S. Food and Drug Administration (FDA), and the almond industry submitted its as part of a petition filed by the International Tree Nut Council Nutrition Research and Education Foundation to the FDA for a heart health claim for nuts. (Walnuts were also included in the International Tree Nut Council petition.) The FDA approved a qualified health claim for walnuts, and another for almonds and other selected nuts, on July 15, 2003, which states: "Scientific evidence suggests but does not prove that eating 1.5 ounces per day of (specify nut) as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease."

Promoting health benefits

Each of these four commodity groups has used news releases and public relations to publicize the nutrition and health benefits of their products. The messages for walnuts and avocados have been communicated almost entirely through third parties such as magazines, newspapers, doctors, nutritionists or other credible sources, rather than paid advertising. The advertising emphasis for walnuts and avocados has been on quality, taste and recipes.

The Almond Board of California initially relied on public relations to disseminate its message on the health and nutritional benefits of almonds. Following FDA approval of their qualified health claim, their research results were incorporated into paid advertising and promotion, almost always featuring a health message. Likewise, in 2003 the California Strawberry Commission introduced a promotion campaign called "Be Well — Get the Red Edge" (Kaiser et al. 2005), which targets health and nutrition professionals, and consumer and trade media.

Commodity groups have found that they can stretch their promotion budgets by partnering with other groups. After FDA approval of the qualified heart health claim for nuts, the Almond Board of California partnered with the American Heart Association (AHA) and now makes liberal use of the AHA logo in almond advertising. The California Walnut Commission formed

a partnership with the Spanish Heart Foundation, and distributed more than 40,000 brochures and samples during "Heart Week" in Spain. The foundation also includes recipes and other information concerning California walnuts on its Web site. The California Avocado Commission is also leveraging its research results by partnering with health organizations, including the American Diabetes Association, UCLA Nutrition Education, American Association of Diabetes Educators, American Dietetic Association and IDEA Health and Fitness Association.

Including imports in marketing

Imports can easily create a "free rider" problem for U.S. commodity programs. California avocado producers spent more than $182 million on market development between 1961 and 2003 (Carman 2006). They were understandably upset to see producers in other countries taking advantage of state promotional efforts when the national market share of imported avocadoes increased from less than 3% prior to 1990 to about 34% from 1998 through 2002. With the 2002 passage of the Hass Avocado Promotion and Research Order (HAPO), all Hass avocados sold in the United States, including imports, are assessed 2.5 cents per pound to fund advertising, promotion, research and data dissemination. Increased avocado demand due to HAPO promotion will offset much of the price impact of increased imports, and importers should enjoy attractive returns from their promotion dollars. Carman (2006, p. 476) estimated that returns for importers' spending on advertising and promotion ranged from $2.09 to $6.31 per dollar spent, depending on the level of imports and the effectiveness of Hass avocado advertising.

Information programs

An important and often overlooked benefit of mandated marketing programs, in addition to having an organized commodity group, is the value of the information they gather, organize and disseminate. A first-of-its-kind innovation for commodity groups was the establishment, by the Hass Avocado Board (HAB), of a Web-based program (www.avohq.com) designed to exchange crop and marketing information among 100 packers and over 20,000 producers from the five HAB members — California, Chile, Dominican Republic, Mexico and New Zealand.

The HAB Web site notes: "The program goal is to develop collaborative strategies to achieve an orderly flow of the 750 million pounds of fruit sent annually into the U.S. marketplace." This Web-based program collects, tracks, analyzes and disseminates information relevant to selling Hass avocados in the U.S. market. It provides all players in the U.S. market with 24-hour access to critical market data that drives decisions about growing, shipping, distribution and marketing.

The HAB market information program is an exciting development in produce marketing, made possible by recent worldwide developments in communication networks. It provides a dramatic reversal of trends that have reduced the availability and timeliness of market and price information for produce markets. The widespread availability of marketing information and data is a theoretical requirement for competitive markets. It will be interesting to see to what degree improvements in marketing efficiency made possible through HAB flow to producers funding the program. If successful, the program template can be extended to other commodities and countries, with benefits flowing to producers and consumers worldwide.

Marketing program trends

California farmers continue to rely on mandated marketing programs for solutions to their marketing problems and as a competitive tool to improve crop returns through demand expansion programs. Forward-looking producer boards appear to be emphasizing customer satisfaction in designing action programs. New commodity research programs on health and nutrition are providing information desired by health-conscious consumers, which is also effective for promotion activities. Mandatory food-safety programs for pistachios and almonds offer benefits to both producers and consumers. Finally, the market information program initiated by HAB is an innovative development based on the latest information technology, which is designed to increase marketing efficiency by smoothing the flow of avocados through the distribution network to retail customers. If this program is successful, the model has the potential to be extended to other commodities and countries, with benefits flowing to producers and consumers worldwide.

H. Carman is Professor Emeritus of Agricultural and Resource Economics, UC Davis.

References

Alston JA, Zilberman D. 1998. Science and Technology in California Agriculture. UC Agricultural Issues Center, Issues Brief No 4. http://aic.ucdavis.edu/pub/briefs/brief4.html.

Becker GS. 2007. Federal Farm Promotion ("Check-Off") Programs. Library of Congress, Congressional Research Service. Order Code 95-353, updated April 17, 2007.

Carman HF. 2006. Offsetting price impacts from imports with generic advertising and promotion programs: The Hass Avocado Promotion and Research Order. Rev Ag Econ 28(4):463–81.

[CDFA] California Department of Food and Agriculture. 2007. California Leafy Green Products Handler Marketing Agreement. Marketing Branch. Sacramento, Feb 10. www.caleafygreens.ca.gov.

[GAO] US General Accounting Office. 1985. The Role of Marketing Orders in Establishing and Maintaining Orderly Marketing. Comptroller General, Washington, DC. GAO/RCED-85-57, July 31.

Gray RS, Sumner DA, Alston JM, et al. 2005. Economic Consequences of Mandated Grading and Food Safety Assurance: Ex Ante Analysis of the Federal Marketing Order for California Pistachios. Giannini Foundation Monograph No 46. UC DANR, Berkeley, CA. 60 p. www.agecon.ucdavis.edu.

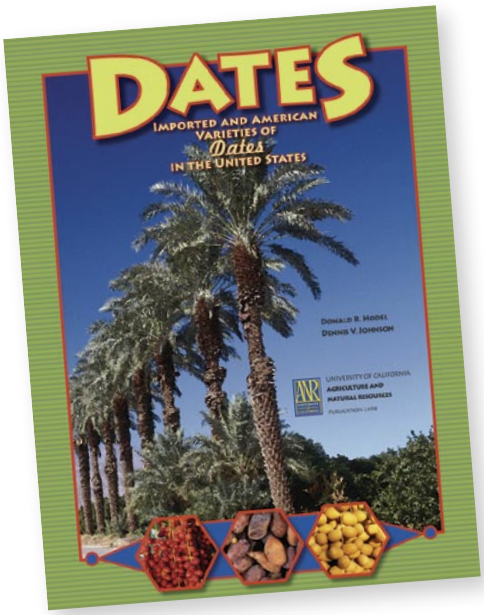
Kaiser HM, Alston JM, Crespi JM, Sexton RJ. 2005. *The Economics of Commodity Promotion Programs: Lessons from California.* New York: Peter Lang Pub. 428 p.

Lee H, Alston JM, Carman HF, Sutton W. 1996. Mandated Marketing Programs for California Commodities. Giannini Foundation Info Ser No 96-1, p 26. UC DANR, Berkeley, CA. www.agecon.ucdavis.edu.

[USDA-AMS] US Department of Agriculture, Agricultural Marketing Service. 2007. Fruit and Vegetable Programs Web site. www.ams.usda.gov/fv/moab.html (accessed June 6, 2007).

[USDA-NASS] USDA National Agricultural Statistics Service. 2005. California Agricultural Statistics, 2004. October 2005. California Field Office, Sacramento, CA. www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/index_casbultn.asp (accessed June 6, 2007).

NEW *from ANR Communication Services*



Imported and American Varieties of Dates in the United States

This book is the first comprehensive account of all varieties of dates and the date palm industry in the United States. It is based on the pioneering work of Roy W. Nixon, the leading American date scientist of the 20th century, and supplemented by the up-to-date research of UC and industry experts. While written with the California and Arizona commercial growers in mind, backyard hobbyists and palm enthusiasts worldwide will also find this reference invaluable. *ANR Pub 3498, 2007, 112 pp., $25.00*

To order:

Call (800) 994-8849 or (510) 642-2431

▼

Go to http://anrcatalog.ucdavis.edu

▼

Visit your local UC Cooperative Extension office

COMING UP *in California Agriculture*

Low tillage maintains rice yields, controls weeds

Herbicide resistance is a major concern in California rice; this crop has more resistant weed species than any other crop or geographic area of the United States. In the next issue of *California Agriculture* journal, UC researchers report on minimum tillage systems for rice. The crop is not tilled in the spring and a "stale seedbed" is flooded to induce weed seed germination, followed by an herbicide spray (usually glyphosate, alternated with other products) before planting. In field research and interviews with growers, the researchers found that rice yields can be maintained under this minimum tillage system. However, the potential for glyphosate resistance must be carefully managed.

Also:

Job development for youth

▼

Fragmentation of the California wine industry

▼

Floor management for grape vineyards

▼

Navel orangeworm in pistachios

calag@ucop.edu
Phone: (510) 642-2431
Fax: (510) 643-5470

Visit *California Agriculture* on the Internet:
http://CaliforniaAgriculture.ucop.edu