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Annual Beef & Range Field Day

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Rangeland Water Quality Management Plan Training Program

John M. Harper
UCCE Livestock & Natural Resources Advisor
Mendocino & Lake Counties

April 22, 1999

Why should ranchers do a water quality management plan?

Extension Specialists, Mel George and Ken Tate, and I, along with local personnel from the Natural Resource Conservation Service (NRCS), have been conducting rangeland water quality planning short courses since early 1994. The five classroom sessions plus a field day course provides landowners with twenty hours of instruction on water quality laws, hydrologic function in upland watersheds and associated streams, identifying nonpoint sources (NPS) of pollution, controlling man-made causes of NPS, writing a letter of intent (LOI) and a management plan, and monitoring the success or failure of the plan and any corrective actions taken. Often the first question that new participants in the course ask is, *"Why should I do a water quality management plan?"*

There are several answers to this question and each course participant ends up deciding which is most important for their ranch operation. A few of the typical answers given are:

- CCA & CFBF support the voluntary approach outlined by the state's California Rangeland Water Quality Management Plan (CRWQMP) and I want to avoid regulations that will direct my ranch management activities.

- By doing a plan I will have an "insurance policy" that should a complaint ever be filed with a regional water quality control board against me I will have documentation that outlines my concern and efforts for protecting water quality.

- The ranch plan and the photo point monitoring pictures become a historical document that I can pass on to my heirs.

- The watershed where my ranch is located must go through a Total Maximum Daily Load (TMDL) process and I want to have my own site specific plan rather than following a generic basin plan for dealing with water quality issues.

- I believe that water quality is just the first of many environmental issues that will affect private landowners and I realize that having a total natural resource management plan will insure that I can deal with these future issues now rather than as each one presents itself. I want control of my destiny when it concerns my property.

What groups other than ranchers have been trained?

When the course was first started the primary audience was rangeland owners or managers. In order to get acceptance of the individual plans it be came clear that we had to let a larger audience know about the training that these landowners were receiving. We did this by promoting the voluntary process to several different groups or agencies. Informational talks on the short course were given to the Resources Agency, State Water Resources Control Board, North Coast Regional Water Quality Control Board, local Resource Conservation Districts, local and state Farm Bureau, CDF and the Forest Landowners of California, local cattle and sheep producer associations and a few existing watershed groups. We even visited with local and state elected officials including Mike Thompson, Wes Chesboro and Virginia Strom-Martin.

With the completion of the first TMDL for sediment in the Garcia Watershed, Ken Tate and I discovered that we were dealing with Regional Water Quality Control Board and EPA staff -- those folks charged with writing TMDL's -- who knew little about ranching or agricultural management. They were also very skeptical of the *"voluntary process"* and what was being taught in our short courses. It was apparent that we needed to provide an intensive overview of the course for these regulators. We did exactly that with a two-day course - one day in a classroom and one day in the field. By doing so the regulators gained invaluable experience in what we put landowners through in the 20-hour short course. We plan to do additional intensive training sessions for State Farm Bureau staff, the State Water Resources Control Board, California Fish and Game and the National Marine Fisheries Service.

Largely because of the TMDL process in the North Coast our audience for the short course is expanding rapidly. We now have vineyard and orchard owners or managers, hay and pasture produces and registered professional foresters (RPF's) taking the course. And because the Clean Water Act effects everyone living in a watershed, county and city personnel are beginning to sign up for training as well. We expect that Cal Trans and local rural home owners associations will be present in the future.

What were the impacts of training?

Statewide the impacts have been quantified by total ranches completing the course and total acreage being covered by LOI's or plans. In 1997-98 100 ranches covering nearly 500,000 acres under water quality plans were the result of 12 short courses. Prior to that statewide effort more than 60 water quality plans were completed in the North Coast counties of Mendocino and Marin during 1994-96. In 1997-98 more than 30 plans covering more than 100,000 acres were competed during three short courses in the same counties.

In addition to these statistics the training efforts have impacted policy. The North Coast Regional Water Quality Control Board adopted Resolution 97-114 that supports the voluntary approach and specifically endorses the UCCE Water Quality Planning Short Course. The Garcia TMDL for sediment, a phased approach, calls for voluntary participation in the UCCE Water Quality Planning Course and identifies the LOI as showing good faith towards meeting water quality objectives. It also states that the plan prepared through the course could be used as a site specific plan for the implementation and attainment strategy called for in the TMDL. Eighty-one percent of the Garcia landowners complete the water quality planning short course.

As a result of the Garcia landowner participation in the training UCCE was given the responsibility for determining the monitoring methods for baseline and subsequent data for TMDL site specific sedimentation reduction plan. The Sediment Inventory and Prioritization Worksheet which was developed by David Lewis, Ken Tate and John Harper is now widely accepted and is being promoted as a simple and efficient means for landowners to complete sedimentation site inventories. Both EPA Region 9 and the Region 1 Water Quality Control Board are promoting this tool and the planning process as a result of their intensive training.

In addition to the impacts mentioned above several local watershed groups organized by the local Farm Bureau are forming to prepare for the TMDL process and to become an active voice in the creation of NPS pollution reduction plans. There are five such groups that have formed and include the Garcia Watershed Group, Russian River Watershed Group, Navarro Watershed Group, McNab Creek Watershed Group, and the Willits Watershed Group. The Chair and Co-chairs of these groups are graduates of prior short courses.

What are the supplemental materials given out in a water quality course on the North Coast?

In addition to the two standard notebooks of information the following list of materials are routinely given out at short courses offered on the North Coast:

- *CA Salmonid Stream Habitat Restoration Manual* - January 1998. Flosi, Downie, Hopelain, et al. Published by State of California, The Resource Agency, CA Department of Fish & Game, Inland Fisheries Division.

- *Handbook for Forest and Ranch Roads, A Guide for planning, designing, constructing, reconstructing, maintaining and closing wildland roads* - June 1994. William E. Weaver, PhD. and Danny K. Hagans, Pacific Watershed Associates in cooperation with the CA Department of Forestry and Fire Protection and the USDA Soil Conservation Service.

- *Residual Dry Matter (RDM) Monitoring Photo Guide* - 1998. Published by Keith Guenther, Wildland Solutions, Clyde, CA.

- *Groundwork - A Handbook for Erosion Control in North Coastal California* - 1987. Liza Prunuske, prepared for the Marin County Resource Conservation District with funding from the California Coastal Conservancy.

- *Cover Cropping in Vineyards, A Grower's Handbook* - December 1998. Edited by Chuck A. Ingels, Robert L. Bugg, Glenn T. McGourty, and L. Peter Christensen for University of California Division of Agriculture and Natural Resources (Publication 3338).

- *California Water Quality Assessment Report* - January 1997. Published by State Water Resources Control Board and CA Environmental Protection Agency.

- *The Climate of Mendocino County* published by UC Cooperative Extension - Mendocino County.

- *The Climate of Lake County* (reprinted from NRCS Soil Survey)

- *Hydrologic Basin Planning Area Maps* (for appropriate areas).

- *California 305(b) Report on Water Quality* - August 1996. Published by the State Water Resources Control Board.

- National Marine Fisheries Service Maps: *Steelhead Scientific Findings - Coastwide Steelhead Status 15 ESUs*- March 13, 1998, *Steelhead Scientific Findings - 5 ESUs* - March 13, 1998, *Coho Salmon Status-OR, WA, and CA* - June 17, 1997.

- *USDA Soil Survey Maps* (for appropriate areas).

- *State and Federally Listed Endangered and Threatened Animals of CA* - July 1998. Published by the State of CA, The Resources Agency, Department of Fish & Game, Natural Heritage Division.

- *Russian River Practices/Components Report for Conservation Technical Assistance* (EQIP Project 0619)

- *"How to Manual" for development of local watershed working groups to implement California Farm Bureau's Nonpoint Source Initiative* - published by California Farm Bureau.

- State Water Resources Control Board Resolutions #98-055 and #98-066.

As new information becomes available it is added to this list of supplemental materials. The general philosophy is not to overwhelm the course participant but to put the needed information into the landowners hands so they will be fully prepared to participate in both the resource management of their land and in the TMDL process.

Rangeland cattle and the risk of waterborne *Cryptosporidium parvum* infection in humans

Rob Atwill, DVM, PhD

Department of Population Health & Reproduction and Veterinary Medicine Extension
Veterinary Medicine Teaching and Research Center
School of Veterinary Medicine
University of California, Davis
18830 Road 112, Tulare, CA 93274

Background:

Cryptosporidium parvum (*C. parvum*) is a tiny protozoal parasite that can cause gastrointestinal illness in a wide variety of mammals, including humans, cattle, sheep, goats, pigs, and horses. It also occurs in various wildlife species such as deer, raccoons, opossums, and rabbits (Fayer et al. and Ungar 1990). In cattle, clinical disease and shedding of the parasite is usually limited to calves under a few months of age (National Animal Health Monitoring System 1994, Kirkpatrick 1985, Anderson and Hall 1982). Although not confirmed by studies done in the U.S., researchers in England and in Spain have reported the shedding of *C. parvum* in adult beef cattle (Scott et al. 1994, Lorenzo Lorenzo et al. 1993). In humans, clinical disease and shedding can appear at all ages, but is typically more common among children (Ungar 1990). The predominant clinical sign is profuse, watery diarrhea lasting from a few days to several weeks in normal (immunocompetent) calves (Kirkpatrick 1985) and humans (Jokipii and Jokipii 1986). While this disease is usually self-limiting in immunocompetent calves and humans, it can be prolonged and life-threatening among immunocompromised people such as AIDS patients. An effective treatment for eliminating this parasite from the gastrointestinal track still does not exist (White et al. 1994, Goodgame et al. 1993). A few antibiotics may show some promise in reducing the amount of oocyst shedding in AIDS patients, but further clinical trials are needed to fully evaluate their efficacy (White et al. 1994, Goodgame et al. 1993). The severity of this disease for the immunosuppressed and the fact that this parasite was implicated in recent large scale water-borne outbreaks of gastroenteritis in humans (MacKenzie et al. 1994, Hayes et al. 1989) has prompted the U.S. Environmental Protection Agency (U.S. EPA), Centers for Disease Control and Prevention, state and local public health agencies and regional water districts to seek ways to reduce surface water contamination of this parasite. Some of this attention has focused on identifying the primary sources of *C. parvum* in surface water. Cattle are often perceived to be a leading environmental source of water-borne *C. parvum.* For example, the U.S. EPA has explicitly warned that inclusion of *C. parvum* into the proposed Enhanced Surface Water Treatment Rule will likely result in new restrictions being placed on the location and management of livestock operations situated within watershed regions (U.S. EPA 1994). Presented below is a brief summary of the medical ecology of *C. parvum* in calves and in humans and the existing scientific evidence that addresses the claim that grazing of cattle on watershed regions puts humans at significant risk for water-borne infection of *C. parvum*.

Life cycle:

In calves and in humans, transmission occurs when an infected individual fecally sheds oocysts (eggs) of this parasite into the environment and a susceptible individual inadvertently ingests these oocysts either directly or indirectly through such vectors as contaminated water. The parasite then invades the epithelium of the intestine, replicates, and through sequential reproductive cycles can result, as in the case of calves, in the fecal shedding of up to 10^{10} oocysts per day and up to 10^7 oocysts per gram of feces (Blewett 1989). Shedding of oocysts can last for 3-12 days in calves (Anderson 1981), allowing for heavy concentrations of oocysts to build up in confined operations. A similar pattern is seen humans, whereby infected individuals can shed up to 10^5-10^7 oocysts per gram of feces (Goodgame et al. 1993), with a duration of shedding varying widely from individual to individual and which can range from a few to more than 50 days (Jokipii and Jokopii 1986). Once shed, these oocysts are immediately infective to another individual, allowing for the rapid spread of this parasite within a group of susceptible individuals.

Oocysts shed from one species of mammal appear to be infectious to other species of mammals. Oocysts from humans have been shown to be infectious to a wide variety of livestock and companion animals (Fayer et al. 1990). Oocysts from calves and possibly other mammals appear to be infectious to humans (Dupont et al. 1995, Fayer et al. 1990). People working with diarrheic calves infected with *C. parvum* have themselves become infected with *C. parvum*, presumably from the calf. However, working with diarrheic calves is not common for the general public.

The issue:

The critical issue is how would *C. parvum* from calves gain access to surface waters and end up in drinking water supplies. The essential steps must include calves becoming infected and shedding the oocysts in their feces. These oocysts must then enter a surface water supply and remain infective as they journey downstream to water treatment plants and distribution systems.

How common is it for calves with access to surface water to shed this parasite? Few studies have been done in beef calves, with most research conducted on dairy calves. Dr. Atwill, University of California-Davis, has been testing cattle from rangeland cow-calf operations from throughout California and has found that most infections are limited to calves under 5 months of age (See Figure 1) (Atwill et al., 1998). One of the largest surveys to date on shedding of *C. parvum* in beef calves was conducted by the USDA's National Animal Health Monitoring System in cooperation with USDA's National Veterinary Services Laboratories. Twenty percent of diarrheic calves (n=391) and 11% of non-diarrheic calves (n=1,053) from a total of 210 operations were found to be shedding *C. parvum* oocysts at the time of sampling (National Animal Health Monitoring System 1994). Around 40% of these 210 operations had one or more calves shedding *C. parvum* oocysts at the time of sampling. In this same study shedding of oocysts was documented in 9% of asymptomatic calves between 3 and 6 months of age, indicating that shedding can occur in these older age groups and without clinical signs. In Manitoba, Canada, 22% of beef calves from 148 herds known to have problems with neonatal diarrhea were found to shed *C. parvum* (Mann et al. 1986). In England, 36-39% of diarrheic beef calves tested positive for *C. parvum* while only 8% of healthy beef and dairy calves tested positive (Reynolds et al. 1986). From across the United States, 22% of 7,369 dairy calves tested positive for this parasite (Garber et al. 1994).

Wildlife considerations:

We are just beginning to study the prevalence of shedding among wildlife species with access to surface waters, but much more research is needed in order to fully understand what contribution wildlife make to surface water contamination. In a survey of 100 raccoons, 13 juveniles had oocysts in their feces (Snyder 1988). Cryptosporidial infection has been confirmed in grey squirrels (Sundberg et al. 1982) and in a large variety of neonatal captive deer, including mule deer (Heuschele et al. 1986). Thirty percent (35/115) of wild mice trapped at a dairy shed oocysts (Klesius et al. 1986). Oocysts obtained from these mice were shown to be infective to calves, perhaps indicating a mouse-calf cycle. Sixty three percent (46/73) of wild brown rats trapped on rural farms were shedding *C. parvum* (Webster and MacDonald, 1995). Atwill et al., 1997, found that 12 (5.4%) of 221 California feral pigs were shedding *C. parvum* oocysts. Younger pigs (≤8 months) and pigs from high density populations (>2.0 feral pigs/km^2) were significantly more likely to shed oocysts compared to older pigs (> 8 months) and pigs from low density populations (≤1.9 feral pigs/km^2). Given the propensity for feral pigs to focus their activity in riparian areas, feral pigs may serve as a source of protozoal contamination for surface water.

Human considerations:

The prevalence of shedding among groups of people is highly dependent on which country, which population, and can range from 0-60%, with the higher proportion of shedding among diarrheic individuals (Ungar 1990). The Centers for Disease Control and Prevention estimates that the overall background prevalence of shedding in the United States is around 0.5-1.0%, but the relationship between shedding in humans and levels of viable *C. parvum* oocysts in surface water contamination remains unknown. Outbreaks of human cryptosporidiosis have been linked to swimming in pools (Bell et al. 1993). Also unknown is what proportion of cryptosporidiosis in humans is due to water-borne infection as opposed to human-to-human direct infection.

Survivability:

How long do *C. parvum* oocysts survive in the environment once they are shed in feces? Oocysts became non-viable after several hours of in-door drying at room temperature (Robertson et al. 1992). Oocysts recovered from calf fecal patties which had been kept inside a barn (summer) or inside an unheated shed (winter) became non-infective for 3-7 day old mice in 1-4 days (Anderson 1986). If fecal material thoroughly dries before reaching water, the oocysts would presumably become non-infectious for animals and humans. Ten or more days of freezing at -22°C caused over 90% of oocysts to become non-viable (Robertson et al. 1992). Using mice to determine infectivity, as few as 24 hours of freezing at -20°C or as few as 7 days of freezing at -15°C appeared to render the oocysts non-infective (Fayer and Nerad, 1996). This would suggest that oocysts shed by calves during winter conditions may not survive through the season. Oocysts in distilled water became non-infective if heated to 72.4°C or higher for 1 minute or if heated to 64.2°C or higher for 2 minutes (Fayer 1994). What if fecal material is deposited directly in a stream? One study found that after 33 days in river water, an estimated 40-44% of purified oocysts were incapable of excystation. After 176 days, 89-99% were estimated to be incapable of excystation (Robertson et al. 1992). Approximately 67-88% of oocysts were still viable after 33 days when kept in manure at 4°C (Jenkins et al., 1997; Robertson et al. 1992). Environmental survival of *C. parvum* is an area of active research and we should have considerably more information in the next few years regarding how quickly oocysts die in our western climates.

It may be that most oocysts do not remain infective as they journey from infected calves to surface water to water treatment plant to human consumption. Although there are severe environmental pressures for oocysts to remain infective when excreted on land, apparently only a few oocysts would need to remain viable in order to pose a risk to humans. Experimental studies in healthy humans determined that the infectious dose at which 50% of subjects acquire infection (ID_{50}) was 132 calf-derived oocysts, with as few as 30 oocysts sufficient to induce cryptosporidiosis (Dupont et al. 1995).

Cattle and *Cryptosporidium* in water:

What evidence directly links the presence of *C. parvum* in surface water supplies to livestock production? In attempting to answer this question, one must test samples of water which is a procedure with some limitations. Environmental studies to date have had a difficult time determining if the *Cryptosporidium* found in surface water is *C. parvum* or some other *Cryptosporidium* species not infectious to humans, potentially not shed by cattle, yet detected by one of the laboratory assays used for environmental testing. For example, it appears that *C. muris* which is shed by cattle, rodents, and other mammals, *C. meleagridis* which is shed by turkeys, *C. serpentis* which is shed by snakes, and various other isolates of *Cryptosporidium* found in lizards can cross-react to some degree with the Merifluor monoclonal antibody produced by Meridian Diagnostics, Inc. (Graczyk et al., 1996; Smith and Rose 1990). All of these species of *Cryptosporidium* are not known to be infectious to humans. Dr. Atwill has confirmed in his laboratory that isolates of *C. muris* obtained from adult dairy cattle from the central San Joaquin Valley in California can cross react with the Merifluor monoclonal antibody. Hence, the possibility of false positives is very likely when testing water for *C. parvum*. On the other hand, the recovery efficiency for testing raw water samples, which is the estimated proportion of oocysts recovered out of all oocysts initially present, can vary from below 10% to as high as 60% (Smith and Rose 1990). Hence, water samples with lower concentrations of oocysts could be erroneously classified as negative. With these limitations in mind (likelihood of false positives or false negatives), *C. parvum* oocysts are quite common throughout the surface water supplies of the United States. For example, 50-60% of raw water samples from primarily Midwest and East Coast surface water sources were positive for *Cryptosporidium* oocysts. The geometric mean of detectable levels of *Cryptosporidium* oocysts was 2.4-2.7 oocysts/Liter, with a range between 0.07 and 484 oocysts/Liter (LeChevallier and Norton 1995, LeChevallier et al. 1991). Rose, 1988, detected *Cryptosporidium* oocysts in 51% of 111 raw surface water samples from 13 states. Large west coast rivers in Washington and in California were found to have concentration of *Cryptosporidium* oocysts ranging from 2 to 112 oocysts/Liter, with a mean of 25 oocysts/Liter (Ongerth and Stibbs 1987). Yet, the link between beef cattle grazing and elevated levels of *Cryptosporidium* oocysts in surface water is not very clear. For example, one study found little difference in the concentration of *Cryptosporidium* oocysts from protected surface waters (0.3-4.0 oocysts/Liter) as compared to surface waters subject to agricultural run-off (0.1-2.0 oocysts/Liter) (LeChevallier et al. 1991). Moreover, 68% of these oocysts had become non-viable. Another study measured 5,800 oocysts/Liter in irrigation canal water running through agricultural acreage with cattle pastures (beef or dairy not specified), compared to 127 oocysts/Liter in river water subject to human recreation and 0.8 oocysts/Liter for stream water exposed to ranch land runoff (Madore et al. 1987). One of the most compelling studies to date was conducted on grazed watersheds in British Columbia. They found concentrations of *Cryptosporidium* oocysts in river water to be higher just below a cattle ranch (13.3 oocysts/100 Liters) compared to the just above the ranch (5.6 oocysts/100 Liters) (Ong et al, 1996). These differences appeared to be limited to the period when young calves were present on the watershed and presumably rainfall events were occurring (spring). It would be interesting to know whether increases of waterborne *Cryptosporidium* would have occurred in the absence of young calves or rainfall. Unfortunately, the species of *Cryptosporidium* was not specified, but was most likely *C. parvum* since the increase in waterborne *Cryptosporidium* was most dramatic during and just following the calving season. *Cryptosporidium* oocysts from pristine surface waters have been found to contain 0.005-18 oocysts/Liter, indicating that this organism occurs naturally in pristine watersheds (Madore et al. 1987). This would suggest that wildlife need to be carefully examined for their role in contaminating surface water with this parasite.

Diagnostic procedures for fecal samples:

Sensitive and specific procedures are needed for rapidly diagnosing clinical cryptosporidiosis in humans and animals and for detecting *C. parvum* in environmental samples which may serve as reservoirs of infection. A variety of antemortem procedures are available for diagnosing *C. parvum* infections in mammals. The majority of procedures are designed to detect oocysts in human or animal fecal samples. Direct smears of diluted fecal samples is a very basic procedure, but suffers from low sensitivity and the necessity of differentiating yeast and other organisms from oocysts (MacPherson and McQueen 1993). Concentration procedures, such as sedimentation using formalin-ethyl acetate (Weber et al. 1992) or flotation over sucrose (Current 1990) or salt solutions such sodium chloride (Weber et al. 1992) or sodium dichromate (Johnson et al 1997), can increase the sensitivity of the test (probability of detecting an infected individual given that it is infected), yet one must be able to differentiate a variety of microscopic particulate matter from oocysts (for a review see Arrowood 1997 and Current 1990). Various stains have been developed to improve the specificity and sensitivity of detecting *C. parvum* oocysts in dried fecal smears. Common stains include Ziehl-Neelsen (Heriksen and Pohlenz 1981), Kinyoun, and auramine and rhodamine (MacPherson and McQueen 1993). While the Ziehl-Neelsen acid fast procedure requires only a light microscope, the auramine and rhodamine procedure requires fluorescent microscopy. It should be kept in mind that some stains will cross-react with particulate matter in the fecal sample such as some yeasts, creating the possibility of false positives.

A variety of monoclonal-based procedures have been developed for detecting *C. parvum* oocysts in fecal samples. A direct immunofluorescent antibody test (Merifluor *Cryptosporidium/ Giardia*) has been evaluated and does not to cross-react with non-*Cryptosporidium* protozoa, helminths egg and larvae, and various bacteria and yeast commonly found in human stool samples (Garcia et al 1992), but a rigorous evaluation has not been performed for the diversity of microorganisms found in domestic animal manure. Using human fecal samples, this direct immunofluorescent antibody test was shown to reliably detect down to 5,000 oocysts per gram of watery stool and 50,000 oocysts per gram of formed stool (Weber et al 1991). We have found in our laboratory that this test can reliably detect 1000 oocysts per gram of ruminal bovine manure (unpublished data). Commercially available enzyme-linked immunosorbent assays are now available which have a similar sensitivity to direct immunofluorescence and which can eliminate the time consuming task of microscopic examination of each fecal sample (Rosenblatt and Sloan

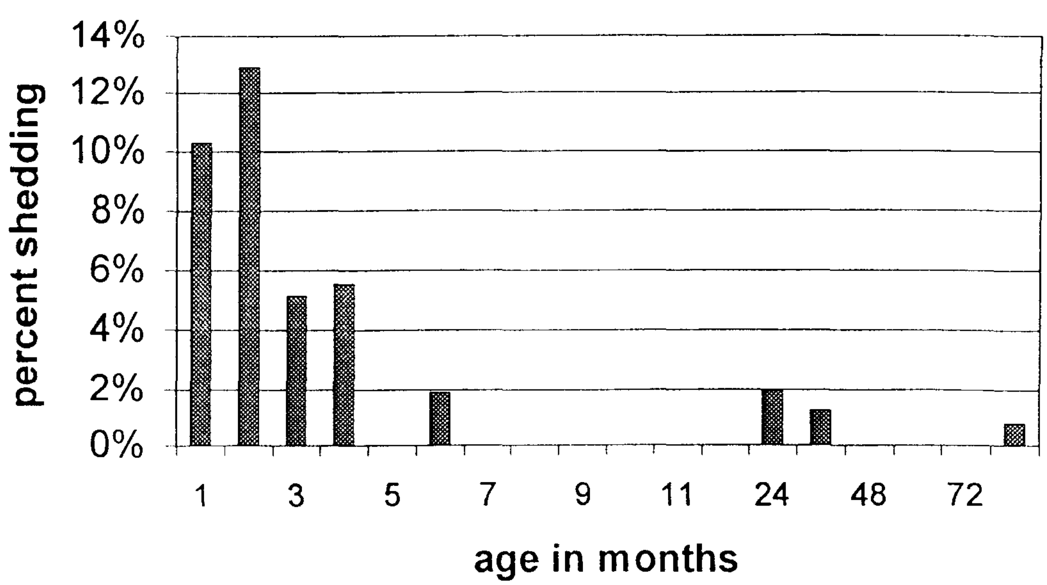
1993). Subsequent work has shown that commercially available direct immunofluorescent assays and enzyme-linked immunosorbent assays cross-react with other species of *Cryptosporidium*, such as isolates of *C. muris*, *C. wrairi*, *C. meleagridis*, and *C. serpentis* (Graczyk et al 1996). A detailed review of diagnostic procedures for foals can be found in *The Compendium*, 1996, Vol 18: 298-306.

Molecular methods of detecting *C. parvum* oocysts are under rapid development with a growing number of diagnostic primers being developed for the sensitive and specific detection of this parasite in stool or manure samples. These methods have the potential to detect very low numbers of oocysts. Several methods under development are reviewed in Arrowood 1997.

Conclusion:

Until we have more detailed studies which provide a causal link between grazing practices and elevated levels of infective *C. parvum* in nearby surface water across different watersheds, different ranching operations and across different seasons, it would be premature to claim that cattle production is a leading environmental source of infective *C. parvum* for water. The presence of young calves in close proximity to surface water during conditions of rainfall may lead to *C. parvum* contamination of surface water, but these conditions (young calves and rain) are not present year round on our western watersheds. Instead, much of our private and public grazing land enjoys only seasonal rain and calving seasons are in many cases not coincident with this rainfall season. As such, contaminating water with bovine *C. parvum* would be very difficult when young calves are not present or when rainfall is not occurring, unless of course young calves are allowed to defecate directly into streams, rivers, reservoirs or lakes. Lastly, if in the words of US EPA (1994) we are to "minimize the potential for source water contamination" by *C. parvum*, then we must first identify the primary quantitative source(s) of this parasite in the environment, be it livestock, wildlife, humans, companion animals, or human-associated sewage effluent, and continue to unravel the medical ecology of this parasite.

Figure 1: Shedding of *Cryptosporidium parvum* by California cow-calf herds



Transport of *Cryptosporidium parvum* on Annual Rangeland Watersheds

Kenneth W. Tate[1] and Edward R. Atwill[2]

[1] Rangeland Watershed Specialist, Agronomy and Range Science Department, University of California, Davis
[2] Environmental Health Specialist and Epidemiologist, School of Veterinary Medicine, University of California, VMTRC, Tulare, CA

Introduction

Cryptosporidium parvum (*C. parvum*) is a fecal-borne protozoal parasite that can be carried by and cause gastrointestinal illness in humans, domestic animals and livestock, and wildlife. This parasite is transmitted through the fecal-oral route by contaminated water and/or food supplies. There are significant public, regulatory, and municipal drinking water industry concerns about the linkage between range livestock production on source water watersheds, drinking water quality, and human health. A proposed grazing ban on City of San Francisco owned rangelands in Alameda County brought this issue to a head within the State in 1997. Since 1995, we have been conducting an on-going research program examining the potential for hydrologic transport of *C. parvum* oocysts from livestock fecal material to water-bodies on California rangeland watersheds.

In order for bovine-derived *C. parvum* to be a waterborne health risk, the infectious stage of the parasite (oocysts or eggs) must reach source water via direct deposition or via hydrologic transport from uplands. Direct contamination of source water occurs when fecal material is deposited within a stream or its flood plain. In order for livestock feces deposited in upland watershed areas to contaminate source water, oocysts must be mobilized and transported from fecal pats during hydrological events such as rainfall or snowmelt.

Thus, two major questions to be answered are: 1. Do *C. parvum* oocysts move out of fecal deposits with rainfall, becoming available for hydrologic transport to water-bodies during storm events; and 2. Where do livestock deposit their fecal material across a watershed over time, and what environmental and management factors determine this? We have completed two research projects which address these questions, and this presentation is a brief synthesis of this work.

Research Methods

Study Site

Both projects discussed in this presentation were conducted within a 138 ha, grazed experimental watershed on the 1,772 ha San Joaquin Experimental Range (SJER) located in Madera County, CA. This watershed is drained by an intermittent stream, normally flowing from January to early June. The stream is dry during the remainder of the year. SJER is representative of grazed hardwood rangeland in central and southern Sierra Nevada west slope foothills. Upland watershed areas are dominated by the coarse textured Ahwahnee soil series, with soil depths ranging from 0.2 to 0.6 m. Vegetation at SJER is oak woodland/savanna with annual grassland under story.

Transport of C. Parvum from Fecal Deposits

In 1994, three sets of paired overland flow plots (total 6 plots) were constructed on the upland Ahwahnee soil type at SJER. Paired plots (2 replicates) were located on a 10%, 20%, and 30% slope upland site. Each plot was 2 m wide (parallel to slope) by 23 m long (uphill-downhill). A collection system was installed at the bottom of each plot to allow for composite sampling of overland flow from the plot. Plots were protected from grazing and thus livestock fecal deposition for a year prior to, and during, this study. All existing fecal deposits were removed from the plots 1 year prior to the experiment. Herbaceous dry matter on the plots averaged 1669 kg ha^{-1} at 2/2/96.

Two experiments were conducted to examine *C. parvum* oocyst mobilization and transport over at least 1.0 m as overland flow from fecal pats during rainfall events. For the first experiment, each of the 6 overland flow plots at SJER was loaded with four 200 g fecal pats dosed with 10^5 *C. parvum* oocysts g^{-1}. This dose and loading rate represents a worst case approximation of oocyst supply by rangeland livestock. On February 2, 1996, the four fecal pats were placed 1.0 m above the bottom of each plot. A composite overland flow sample was collected from each plot following 4 subsequent storm events during the remainder of the 10/1/95 to 9/30/96 water year. Runoff volume from each plot was not measured. Concentration of oocysts were measured for each sample. ANOVA with repeated measures was used to determine significance, with slope (3 levels) as the fixed factor and sample date (4 storm events) as the repeated measure whereby the runoff from 6 plots (3 slopes × 2 replicates/slope) was sampled across 4 storms.

The second experiment was a preliminary trial which arose due to the results of the first experiment. In the second experiment of this project, we conducted a single artificial rainfall experiment to provide preliminary information for development of a future laboratory-based study of the mobilization of oocysts *throughout* a rainfall event. A sprinkler type rainfall simulator was used to apply rainfall at a rate of 7.62 cm hr^{-1} to a 0.5 m^2, 10% slope, ungrazed plot located adjacent to the 10% slope overland flow plot site at SJER. This rainfall intensity exceeds the estimated 100 year return period rainfall event for the site. Rainfall was applied to the plot until equilibrium overland flow had been achieved. At that point four 200 g fecal pats dosed with 10^5 *C. parvum* oocysts g^{-1} of feces were added to the plot. All overland flow from the plot was captured for 90 minutes starting immediately prior to and at 10 minute increments following fecal pat deposition. Concentration of oocysts in the samples were measured for each sample.

Livestock Fecal Loading

In November 1995, 54 permanent 0.004 ha (0.01 ac) belt transects were established across the 138 ha experimental rangeland watershed at SJER. The individual transect was the experimental unit in this experiment. Transects were each 30.5 m (100 ft) long by 1.3 m (4.4 ft) wide and staked at both ends. Following a stratified-random design, the transects were distributed proportionally across the watershed to represent upland slope classes of 0-10%, 11-20%, 21-30%, >30%, and additionally the riparian zone, and all livestock concentration areas in the watershed. Transect numbers per stratification were 14, 15, 5, 5, 10, and 5, respectively. Transects were randomly located within each stratification. The watershed was grazed continuously with a 30 cow commercial-type, cow-calf herd throughout the study period. Fecal load (kg ha^{-1}) in each transect was determined by hand collection and weighing at the end of the wet season (April) and at the end of the dry season (Oct). A complete data set has been collected for 1996-1998. ANOVA was used to examine differences between fecal loading between watershed positions (slopes, riparian areas, concentration areas).

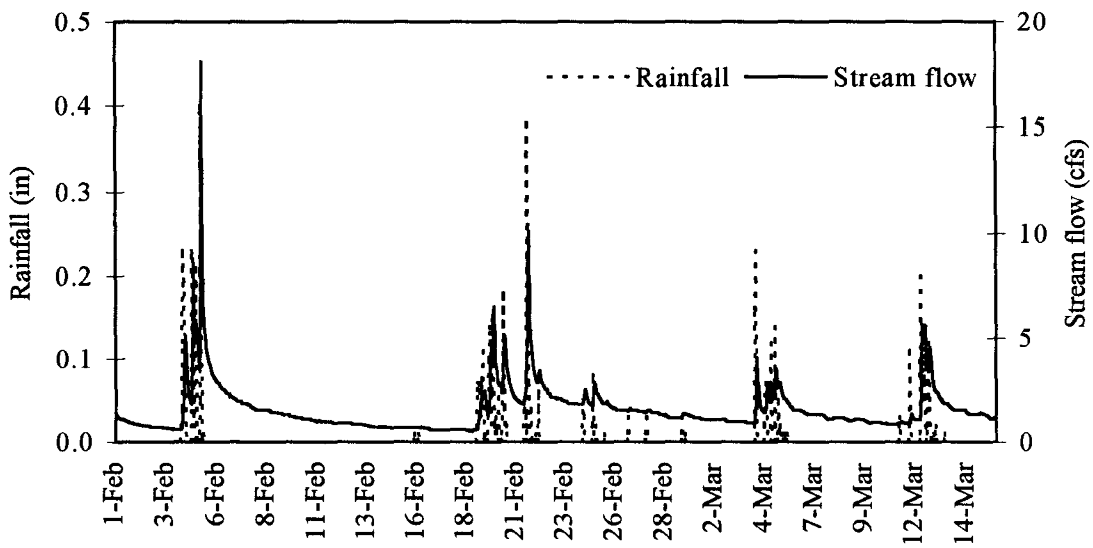
Results

Transport of C. Parvum from Fecal Deposits

Precipitation and stream flow from the 138 ha experimental watershed containing the plots was recorded on a 0.25 hr time step (Figure 1). Overland flow generated by four discrete storm events commencing on 2/3/96, 2/4/96, 2/18/96, and 3/11/96 was composite sampled during the study. Composite overland flow samples from the plots were collected at approximately 1500 hours on 2/4/96, 2/8/96, 2/22/96, and 3/12/96. Total rainfall for the 2/4/96, 2/8/96, 2/22/96, and 3/12/96 sample periods was 46, 55, 64, and 32 mm respectively. Following 3/12/96, no overland flow was realized from the plots for the remainder of the 1995 water year.

Figure 2 illustrates *C. parvum* concentration and storm flow by slope and sample date.

Figure 1. Rainfall and Stream flow from the experimental watershed during the study period.



ANOVA with repeated measures (sample date) reveals that while the effect of slope is significant at the 0.05 confidence level, sample date (storm event) and the potential interaction between slope and sample date were not significant. *C. parvum* concentrations are significantly different at the 10% and 30% slopes, but that neither the 10% and 20% slopes or the 20% and 30% slopes are statistically different. Greater concentrations of *C. parvum* were detected in the runoff with increasing slope. Although sample date was not significant, there is a tendency for oocyst concentrations to decline with sample date (Figure 2). Concentrations for the 2/22/96 sample period were much lower than the 2/4/96 and 2/8/96 sample period, despite the greater rainfall and total runoff during the 2/22/96 sample period. This suggests that the majority of oocysts available for overland transport were "flushed" from the fecal pats and the 1.0 m buffer by the initial storms following fecal deposition on 2/2/96.

Figure 2. C. parvum concentration and rainfall by storm.

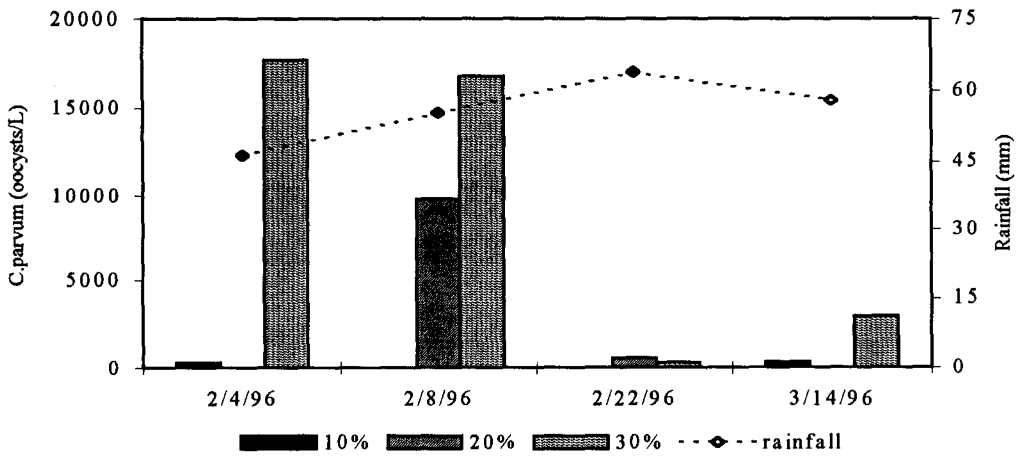


Figure 3. C. parvum concnetration in runoff from rainfall simulator trial.

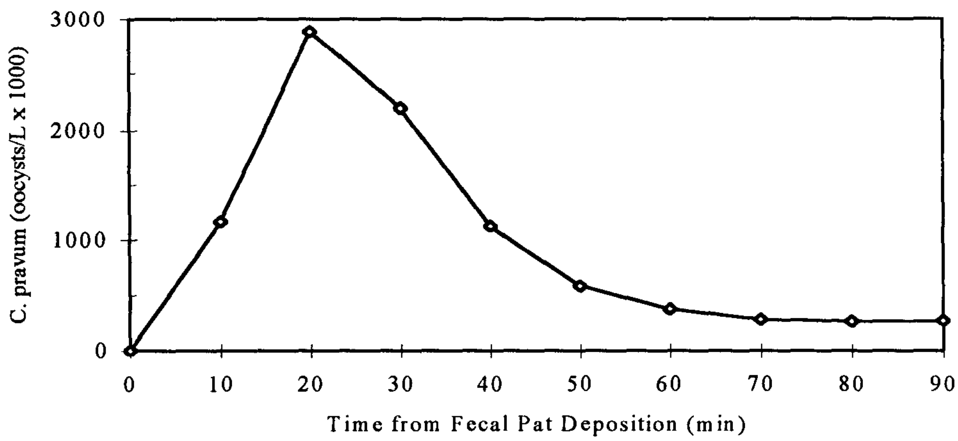
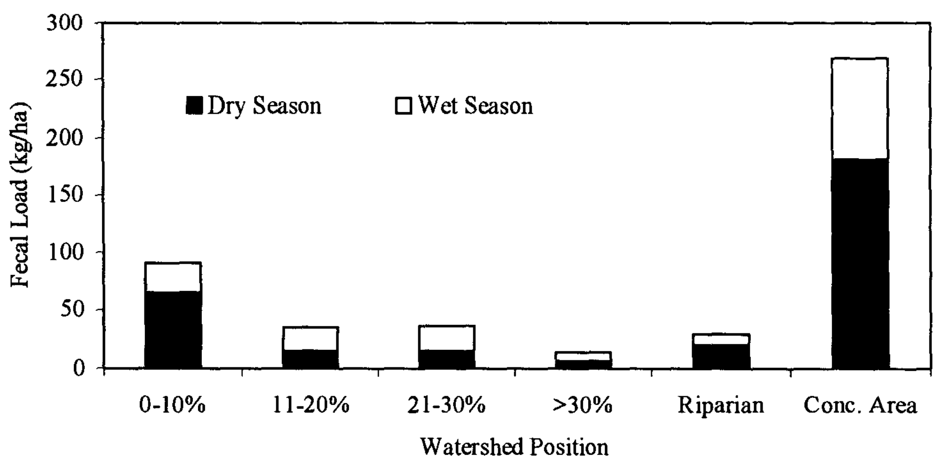


Figure 3 illustrates overland flow volume and *C. parvum* concentration *throughout* the simulated rainfall experiment. There is an evident "flushing" of oocysts during the 90 minute rainfall simulation period. The majority of the oocysts available for overland transport left the plot early in the simulation, with a tailing effect after time 60 minutes. Given that equilibrium overland flow (12 ml min^{-1}) was occurring throughout the experiment, the "flushing" effect is a function of oocyst supply for transport rather than the transport potential, which was constant. This trial also provides insight into the ratio of overland flow to subsurface flow on these hillslopes. At a rainfall intensity of 7.62 cm hr^{-1}, a 90 minute simulation, and a plot area of 0.5 m^2, 28.57 L of water were applied to the plot but only 1.08 L of overland flow left the plot. Assuming no loss to interception or evaporation, 27.49 L (96%) of applied rainfall left the plot as subsurface flow This indicates that leaching of oocysts via subsurface flow is likely the major transport path on these rangelands, and is the next logical hillslope transport process to examine.

Livestock Fecal Loading

Figure 4 reports average fecal loading to the SJER experimental watershed by season and watershed position. The sum (stack) of dry and wet season represents the average annual load per watershed position. Data used are from 1996-97. Dry season is the period May 1 to Oct 31. Wet season is the period Nov 1 to April 30. ANOVA indicates there is no significant difference in average annual loading between any of the upland slope classes or the riparian area. However, there is significantly greater loading for both seasons and the year at the livestock concentration areas. Preliminary analysis also suggest that there is a season effect on livestock fecal deposition patterns. Fecal loading to the 0-10% slope, riparian area, and concentration areas is greater during the summer months. Recall that the stream is dry from Jun to Dec. However, during the winter months when green forage and surface water is abundant, there is more uniform fecal loading across the watershed.

Figure 4. Livestock fecal loading to the SJER experimental watershed by season and watershed position (1999-97).



Conclusions and Management Implications

C. parvum oocysts in fecal pats on rangeland can be mobilized with rainfall, becoming available for transport to water-bodies. Transport of *C. parvum* oocysts increases as slope increases. There is an apparent "flushing" of oocysts by the initial storms following fecal deposition. The rainfall simulation experiment also indicates a "flushing" of oocysts during the first 20 minutes of a storm event. This indicates that there may be pulses of oocysts transported from watersheds during storm flow, with limited transport between storm events. In evaluating the site-specific risk livestock fecal deposits pose to water quality, the hillslope hydrology and stream flow generation characteristics defining transport pathway need to be examined in the watershed of interest. Transport risk will likely be greater on soils with low infiltration capacity (clays, loams) than on those with high infiltration capacity (sands). Livestock management practices which maintains or improves infiltration capacity (proper stocking rate, leaving adequate ground cover, etc.) are best management practices for reducing pathogen transport.

Given that oocysts are mobilized and transported from fecal deposits during storm events, it is critical that management attention be given to the location and timing of fecal loading relative to water-bodies and the wet season. Our findings indicate the power of management measures such as off-site water and supplemental feed location to minimize fecal loading to riparian areas, flood plains, and water-bodies. It also illustrates the great risk to water quality posed by locating water troughs, feed bunks, etc. near streams and riparian areas. While it seems simple, the placement of livestock concentration areas such as stock tanks and feed bunks plays a major role in how livestock fecal material is deposited on the watershed.

GUARDING AGAINST *CRYPTOSPORIDIUM* – A WATERSHED PROTECTION PLAN TO KEEP CATTLE ON SAN FRANCISCO'S WATERSHEDS

Sheila Barry, Ken Tate, Rob Atwill, Tim Koopman, Jim Cullor, and Terry Huff

INTRODUCTION

Waterborne infection from *Cryptosporidium parvum* has become a leading public health issue due to the severity of the disease for immunosuppressed humans, recent waterborne outbreaks of cryptosporidiosis in metropolitan areas of the United States, and the widespread presence of this parasite in U.S. rivers. The most notable outbreak of waterborne cryptosporidiosis, sickened approximately 403,000 people in Milwaukee, Wisconsin, in 1993. Public health officials, land managers, and water districts are under considerable pressure to reduce the risk of water contamination by *Cryptosporidium*.

The primary source(s) of *C. parvum* are not known; however, the assumption that livestock are the primary source recently led some water districts in California to question the presence of grazing livestock in their watersheds. In February of 1997 the San Francisco Public Utilities Commission considered excluding livestock grazing from 40,000 acres of land they own in the Alameda Creek watershed. They wanted to take action to protect their source water from *C. parvum* contamination. However, before the commission was able to vote on this action, they were inundated with oral and written testimony urging them to reconsider the exclusion of grazing livestock from their watershed.

During the testimony, the Commission heard from rangeland scientists that with proper grazing management, risks from livestock contaminating surface water can be minimized, while significant protection from fire hazards could be achieved. Their staff had estimated that without cattle grazing they would have to spend $3.75 million dollars over the next 5 to 10-year period to achieve adequate fire protection (SFWD 1996). Grazing significantly reduces the fire hazard on California's annual grasslands by reducing fuel load and the invasion of woody plants (McBride and Heady 1968). The increased erosion that follows a wildfire is one of the greatest potential contaminant sources to surface water on California's annual grasslands (Montgomery Watson 1995). In addition to fire protection, the Commission heard from wildlife biologists that grazing could be an effective tool for managing some ecosystem types within California's annual grasslands. Proper grazing practices can enhance habitat and the ability of predatory birds, such as the Bald Eagle and Peregrine Falcon to find their prey (USFWS 1993). Grazing annual grasslands can also enhance vegetation, by promoting native, perennial plants, native forbs and wildflowers, and controlling invasive weedy plants (Edwards 1992). In adopting a plan to provide for watershed protection the Commission was asked to consider the variety of potential sources of *C. Parvum* in the watershed, including feral pigs, squirrels, elk, deer, and mice. In particular, they were asked to re-establish a program to control the feral pigs. The Commission was urged to develop and adopt a comprehensive watershed protection plan.

As a result of the letters and oral testimony, on March 4, 1997 the Commission passed a resolution requesting that the Alameda County Resource Conservation District and the livestock industry develop in sixty days, a best management practices plan to guard against *Cryptosporidium*. The District and the industry responded by inviting all interested stakeholders to participate in a process to develop an adaptive watershed management plan.

DEVELOPING AN ADAPTIVE WATERSHED MANAGEMENT PLAN

Since San Francisco's water collection and storage system in the Alameda Creek watershed is part of a dynamic natural system, an adaptive management plan to protect water quality is essential. In building the foundation for an adaptive watershed management plan, all interested stakeholders in the watershed were encouraged to participate. The stakeholders participating in this effort included bay area water districts, AIDS activists, water quality regulators, landowners and cattlemen in the Alameda Creek watershed, and the San Francisco Water Department.

Stakeholder participation began with an informational meeting to discuss the planning process, and hear presentations from University of California researchers studying the source and fate of *Cryptosporidium* in the environment. During this meeting a technical multidisciplinary team was established. The technical team included professionals from the University of California Cooperative Extension, the San Francisco Water Department, the Department of Fish and Game, and the United States Department of Agriculture. A six-hour field tour of the watershed provided an opportunity for stakeholders to discuss and view grazing and wildlife management practices in the watershed. Tour participants also saw the condition, topography, resources and scope of the watershed. The technical team also spent a day touring the watershed.

An adaptive watershed management plan was developed by the technical team by adapting Hazard Analysis Critical Control Points (HACCP), a systematic program synonymous with food safety, to address watershed protection. HACCP developed nearly 30 years ago for the United States Army and NASA, has been adopted by other food service and manufacturing industries (Huss 1992). The overall focus of any HACCP program is to prevent identifiable hazards by controlling them as far "upstream" as possible (Cullor 1995). Applying HACCP to address water quality concerns means working to eliminate potential contaminants from ever reaching source water.

The HACCP-based program for the Alameda Creek watershed included recommendations for livestock grazing management and wildlife management to guard against *Cryptosporidium* and other waterborne pathogens. The program was presented to stakeholders who were asked to review it. The HACCP-based program received unanimous support from all stakeholders and reviewers. The program provides for continued participation of stakeholders in implementing, monitoring, and adapting management practices to protect water quality. San Francisco Public Utilities Commission has been encouraged to continue to involve stakeholders.

IMPLEMENTING A HACCP-BASED WATER QUALITY PROGRAM

An initial analysis of biological (pathogen) hazards in the Alameda Creek watershed identified five management areas for controlling hazards (figure 1).

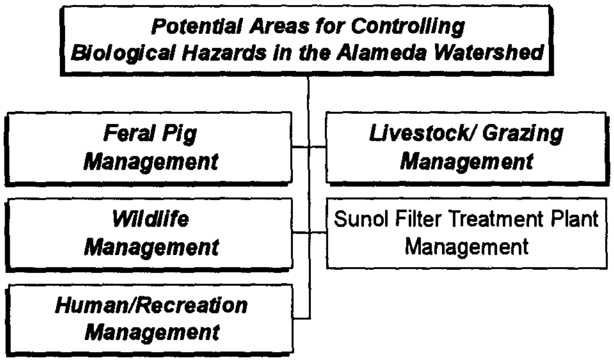


Figure 1. Management Areas for Controlling Biological Hazards in the Alameda Creek watershed.

To address the initial concerns of the San Francisco Public Utilities Commission, the multidisciplinary watershed-based team focused on identifying specific hazards and control points for livestock/grazing management and feral pig management (table 2). In regards to other wildlife management and human/recreation management the multidisciplinary team determined that there was not currently enough information to complete a hazard analysis with control points. However, the team recommended that a comprehensive monitoring program be implemented in order to develop effective management measures for these management areas. The monitoring program would include monitoring fecal samples from selected livestock and wildlife populations in conjunction with strategic water testing. This comprehensive monitoring program could also be used to assure water users that watershed management actions implemented in regard to feral pig and livestock management are effective in protecting water quality.

The team did not review or evaluate the control of potential hazards from management of the filter treatment plant, because San Francisco Water Department has been independently conducting an analysis. However, the team recommended that in conducting their analysis they adhere to HACCP principles. Management measures for the filter treatment plant should be outlined with critical limits, monitoring procedures to test critical limits, corrective actions and recordkeeping.

The preventative management measures described as part of this HACCP-based water quality program, should minimize the potential risk of cattle and feral pigs contaminating source water with *C. parvum* and other waterborne pathogens. However, it should be recognized that in this program, the preventative measures for each management area are recommended without prior testing. While they are widely accepted, and effective range management and wildlife management practices, their effectiveness for protecting water sources from *Cryptosporidium* and other waterborne contaminants are not proven.

With consumer's apprehensions growing with regard to waterborne illness and other water contaminants, a verifiable water quality management program like HACCP is essential to demonstrate the deligence and commitment of water agencies to provide safe drinking water. The overwhelming acceptance of this HACCP-based program among a broad base of stakeholder is not only attributed to the use of a verifiable, science-based approach, but also to diligent efforts to provide an opportunity for stakeholder input in developing the program.

Table 2. Summary of Associated Hazard, Critical Control Point, Preventative Management Measure, and Critical Limits for Controlling Biological Contaminants in the Alameda Creek watershed.

Management Area: Livestock / Grazing		
Associated Hazard	**Critical Control Points**	**Preventative Management Measures and Critical Limits**
Wildfire in the watershed increasing runoff and movement of sediment, which may carry pathogens.	Manage residual dry matter (RDM) to reduce fire hazard.	Manage grazing livestock (season of use, stocking rate) to achieve a target RDM of 700-1000 lbs / acre). Specific RDM target levels for each grazing unit will be prescribed.
Infected cattle directly depositing feces into source water. Infected cattle are primarily calves less than 5 months of age (Atwill et al, 1998)	Minimize the intensity of infection in cattle.	Livestock owners (leasees) establish a herd health program (CCA 1994) for the prevention and care of general parasitic disease, to maintain healthy immune systems, and minimize cryptosporidial infection.
	Control cattle grazing and access to reservoir and riparian areas with fencing (George 1996, Swanson 1986, Swanson 1987).	Maintain reservoir and riparian pastures (buffers) around reservoirs and streams with riparian habitat. No calves under 5 months will have access to reservoir or riparian areas.
Infected cattle depositing feces in the watershed where runoff may carry viable pathogens to source water.	Manage residual dry matter (RDM) to minimize potential for feces transport (minimizing runoff) (Clawson et al, 1982).	Insure good even distribution of livestock utilization and fecal material by controlling grazing utilization and distribution. Improve distribution, where necessary, with water developments, feeding locations, herding or fencing. Control grazing utilization to achieve a target RDM of 700-1000 lbs / acre. Specific RDM target levels for each grazing unit will be prescribed.
	Strategically locate areas of livestock concentration (George 1996, Larsen et al 1994)	Locate areas of livestock concentration to be hydrologically remote. Stock tanks and feeders will not be located in stream channels, swales or flood plains.

Management Area: Feral Pigs		
Associated Risk	**Critical Control Points**	**Preventative Management Measures and Critical Limits**
Infected feral pigs contaminating source water.	Minimize the population and infection rate of feral pigs (Atwill et al 1996).	Reduce pig densities with a persistent, flexible control program to less than 2 pigs/km^2.

CONTROL MEASURES FOR PINKEYE IN CATTLE

Prof. Lisle George, Professor, School of Veterinary Medicine,
University of California at Davis

Infectious bovine keratoconjunctivitis (IBK), commonly known as pinkeye, is a serious disease in California beef cattle, affecting more than 90 percent of calves in some herds. IBK causes Red, teary eyes and ocular ulcers. The infection suppresses appetite and weight gain, resulting in economic loss. Healed infections leave scarring, which rarely leads to total blindness but affects the value of purebred breeding animals and those intended for the show ring.

The infectious agent is the bacterium *Moraxella bovis*. Cattle older than one year become mostly resistant to IBK but often harbor the bacterium in their tears and nasal secretions. The disease is often spread by the face fly, which is MOST abundant from midsummer to early autumn. Other factors influencing the seasonal occurrence of pinkeye is a large number of young, susceptible cattle in the herd.

M. bovis can be treated with a number of antibiotics. Most treatment recommendations, however, are based on anecdotal field observations. Over several years, we conducted scientifically-controlled trials to find the most cost-effective way to treat pinkeye. Recently, we also tested a vaccine candidate for IBK developed in our laboratory.

While the laboratory work was carried out at the Davis campus, the Sierra Foothill Research and Extension Center was chosen for the field work because pinkeye is endemic among the SFREC cattle, affecting most of the weanling calves each year. While this high incidence is not welcomed by management, it provided an excellent research opportunity.

We devised four different trials testing different antibiotics and combination of antibiotics as well as different dosages and application methods. Each trial consisted of three groups of about 20 to 40 calves, except where noted. Two groups received treatment and the third group was left untreated as a control. Over the past three years, we have also begun a separate study with our experimental vaccine, whose design and preliminary results are given at the end of our report.

Treatments Studied

1) Oxytetracycline versus furazolidone

a) 2 intramuscular injections of a long-acting oxytetracycline (LA-200, 20mg/kg body weight) 72 hours apart

b) a topical application of furazolidone spray daily for 3 days;

Intramuscular injections of oxytetracycline combined with 10 days of oral tetracycline can reduce the incidence of pinkeye for the entire summer. This long-lasting protection may be desirable in herds with very high incidence of the disease.

Procaine penicillin G is an effective treatment. When using this option, calves should be treated daily for at least 3 days. The penicillin should be injected directly under skin of the eyeball, not into the upper eyelid. Dexamethasone did not improve the effectiveness in our trial.

Florfenicol (at 40mg/kg once or 20mg/kg twice 24 hours apart) is an effective treatment option.

Vaccine Tests and Results

We have isolated and purified in our lab a cellular factor (cytotoxin) from *M. bovis* that may stimulate an immune response and protect calves from infection with the bacterium. We combined the cytotoxin with three different adjuvants -- water-oil emulsion, immunostimulating complexes (ISCOMS) and aluminum hydroxide--into experimental vaccines. Trials have proven the aluminum hydroxide preparation to be ineffective in protecting against pinkeye. At SFREC, the ISCOMS plus the toxin preparation yielded the lowest incidence of corneal ulcers and other clinical scores. Those ulcers that did appear healed more rapidly after treatment (with oxytetracycline) than those in control animals. However, ISCOMS alone also protected at a low levels. Calves vaccinated with the water-oil vaccine preparation had worse disease than the controls.

Our research is continuing to develop a protective vaccine, saving the need for treatments.

Trichomoniasis Update

Dr. Bob BonDurant
Dept. Population Health & Reproduction, School of Veterinary Medicine
University of California, Davis

The "trich" research effort in the School of Veterinary Medicine involves faculty and staff from two academic departments as well as the California Veterinary Diagnostic Laboratory (CVDLS) and the Veterinary Medical Teaching Hospital (VMTH). The total effort encompasses a wide range of studies, from basic "bench" research on the pathogenesis of bovine trichomoniasis, to vaccine studies, to efforts to improve diagnostic capability.

"Bench Studies"

The major effort at this time is a USDA-funded study on the pathogenesis of bovine trichomoniasis. The essential hypothesis that we are testing is that the causative organism, *Tritrichomonas foetus*, does not directly destroy the pregnancy, but rather that the host (cow) immune response to the organism indirectly destroys the uterine and/or fetal cells that are critical for maintaining pregnancy. If this is true, then improvements in vaccine design will have to take this "immune-mediated" injury concept into account. The studies are in their earliest stages right now, and are being conducted in collaboration with Dr. Linda Munson (Dept. of Pathology, Microbiology, and Immunology), Dr. Mark Anderson (CVDLS), and Dr. Lynette Corbeil (UC San Diego). It's too early to know if our hypothesis is wrong or right, but we do know that the hypothesis is consistent with the results we obtained in a model system, where circulating white blood cells (WBC's) were used as the "target", rather than cells of the pregnant uterus. In that model, when antigen-coated WBC's were exposed to *T. foetus* in the presence of anti-*T. foetus* antibodies, the WBC's were killed over a period of 5 hours, whereas WBC's exposed to *T. foetus* only showed little cell death.

Vaccine Studies

In collaboration with Dr. Lynette Corbeil, we have now completed data collection on four vaccine trials. Dr. Corbeil has isolated and characterized a surface antigen of *T. foetus* that appears to have important "protective properties"; i.e., antibodies to this antigen can agglutinate and immobilize trichomonads, and prevent adhesion to vaginal epithelial cells. When virgin heifers are immunized with purified antigen and then challenged at estrus by infusing one million live *T. foetus* into the vagina, most heifers become infected, but shed the organism significantly faster than the unvaccinated controls. (In one trial, controls began to "clear" the organism by about week 7-8 following infection, whereas the immunized heifers began clearing infection as early as week 3-4.) While the vaccine did not prevent infection, it may still provide significant protection against the <u>consequences</u> of infection, i.e., against abortion, since others have shown that death of the pregnancy in naturally infected cows typically occurs as late at 8-

10 weeks following infection. Clearance of the organisms from the uterus before 8-10 weeks may offer protection against pregnancy loss.

Diagnostic Studies

Over the past several months, our VMTH and CVDLS laboratories have discovered apparently positive trichomonad cultures from bulls that were reported to be virgins. In cooperation with VMTH and CVDLS personnel, as well as with colleagues in Canada, we have been able to partially characterize a "virgin bull" isolate, obtained from the prepuce of at least 14 bulls from three different facilities.

The isolates we have seen have all been presented to the CVDLS or VMTH in InPouches, the diagnostic packet that is widely used as a transport and culture system for *T. foetus*. When the contents of the packet are viewed under a microscope at 100-400 X magnification, the virgin bull trichomonads show the same rolling, jerky motility, multiple anterior flagellae, and an undulating membrane characteristic of true *T. foetus*. Although the organisms are a bit more rounded than *T. foetus*, they are easily mistaken at the light microscope level for the true venereal pathogen.

When these isolates were examined with scanning electron microscopy (SEM), we saw an obviously more rounded organism, many of which had four anterior flagellae, (vs. 3 in *T. foetus*). In addition, stained preparations of all of the "virgin bull isolates" showed very dark, dense-staining packets of material within the cell, something that we don't see in *T. foetus*. The axostyle, a stiff, tail-like appendage on many trichomonads, was prominent.

We further evaluated the "virgin bull trichomonads" by employing a polymerase chain reaction assay. This test isolates a tiny amount of DNA from the organism, and amplifies it on a template, or primer of DNA. We chose a primer developed in Switzerland, and showed that all isolates from our *T. foetus* collection reacted as predicted in the assay, i.e., they yielded an amplification product. Conversely, none of the "virgin bull" isolates yielded an amplification product. Our goal is to develop a practical, affordable test for confirming a diagnosis of trichomoniasis in bulls. It seems clear that the InPouch is a highly sensitive medium, but that it may lack some specificity, thereby creating a situation in which uninfected bulls may be condemned because of false positive diagnoses. Our current goal is to develop a rapid, practical diagnostic method for differentiating true *T. foetus* from these *T. foetus* look-alikes, and to distribute the test to diagnostic laboratories.

Demonstration of Beef Cattle Marketing Alternatives

Larry Forero, Livestock/Natural Resource Farm Advisor, UCCE Shasta County
Glenn A. Nader, Livestock Natural Resource Farm Advisor, UCCE Sutter-Yuba County
J. Michael Connor, Superintendent, UC Sierra Foothill Research & Extension Center

The present cattle market has producers reviewing marketing alternatives. Selling cattle as calves, yearlings or retaining ownership through the feedlot are all options producers consider. This demonstration uses cost and return numbers to discuss the benefits and liabilities of each marketing scenario.

Ten weaned steers were selected in May of 1996, 1997 and 1998. The cattle value is based upon the Friday sale in Cottonwood that week. The weight and value for cattle are estimated in Table A.

Table A. *Weight and Estimated Value at Weaning*

Year	Weaning Wt	$/cwt (May)	Avg $/hd
1996	469 lbs	$59	$277
1997	511 lbs	$79	$404
1998	694 lbs	$79.5	$552

Cattle were summered at SFREC on irrigated pasture gaining 1.36, 1.47 and 1.52 1996, 1997 and 1998 respectively. In late August five head were selected and shipped to McArthur. The weight and value for cattle are estimated in Table B.

Table B. *Weight and Estimated Value of Cattle as Yearlings*

Year	Yearling Wt	$/cwt (Aug)	Avg $/hd
1996	671 lbs	$60	$403
1997	729 lbs	$73.55	$536
1997	858 lbs	$58.5	$502

The cattle were consigned to the InterMountain Fair Steer Futurity in August. The steers were evaluated live as feeder cattle in McArthur and then shipped to a feedlot along with approximately 100 head of steers owned by a variety of Northern California ranchers. Average daily gain was calculated in the feedlot and animals were processed when finished. Payment for animals was based on rail value less feedlot expenses. Average feedlot performance and carcass data are summarized in Table C.

Table C. *Carcass and feedlot attributes*

Year	Wt. In	Wt. Out	ADG	HCW	BF	REA	KPH	Quality	Yield
1996	671	1044	2.80	641	0.41	11.3	2.2	Se	2.78
1997	729	1154	3.38	721	.54	12.6	2	Ch-	2.9
1998	858	1364	4.32	854	.74	14.00	1.8	Se+	3.48

Conclusion

One of the goals of this demonstration was to look at three marketing opportunities for these cattle and determine which afforded the "best" return for that set of cattle. **Table D** demonstrates the value added to the cattle as a result of summering them on irrigated pasture on the Field Station. Cost to summer the cattle was estimated at $.27/lbs gain and $5/head veterinary/medicine charges. No interest or opportunity cost was applied.

Table D. *Economic data associated with summering the cattle at SFREC*

Year	Calf Value	Yrl Value	Cost	Profit (loss)
1996	277	403	60	66
1997	404	536	64	68
1998	552	502	49	<99>

Table D demonstrates that holding the cattle over the summers of 1996 and 1997 netted Back an average of $70 per head over selling the calves off the cows. Holding the calves past weaning was a poor choice in 1998. The market moved down and resulted in a $100 dollar loss last year.

Table E reflects the economics of holding the cattle past the stocker phase was a poor choice in 1996 and 1997. The high cost of feed associated with soft fed cattle market conditions resulted in cattle losing an average of $124.50 per head over their value as feeder cattle. In 1998 the cattle averaged a return of about $19 over their value as feeder cattle.

Table E. *Economic data associated with feeding the cattle*

	1996	1997	1998
Gross Value	$582	$757	$765
Feedlot Costs	$337	$312	$244
Cattle Value	$403	$536	$502
Net	<$158>	<$91>	$19

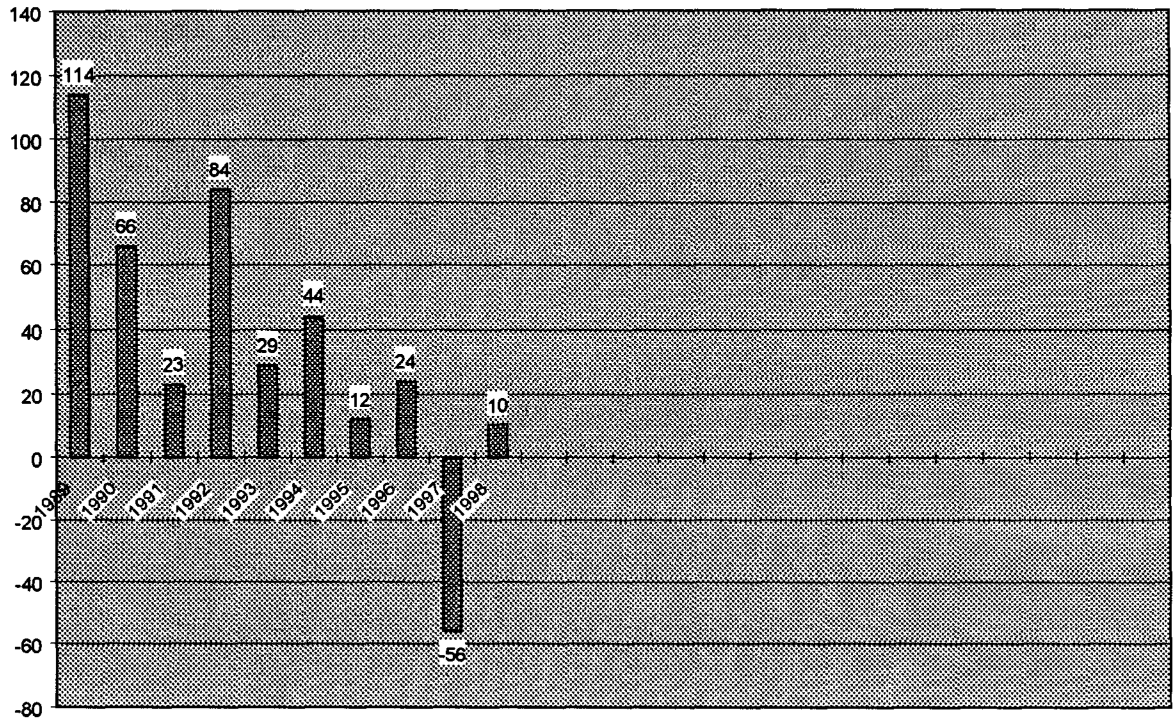


Figure 1. *Demonstrates the ten-year average return over feeder cattle by the participants*

Figure 1 demonstrates the ten-year average return over feeder cattle by the participants Because of the variability in results (demonstrated in Figure 1) the shorts term nature of this demonstration and cannot reflect long term trends. It does, however, point to marketing windows and potential marketing opportunities that require constant evaluation by producers.

Application of Ultrasound in Beef Cattle

R. D. Sainz
Animal Science Dept., UC Davis

There are several situations in which producers can benefit from knowing what is "under the hide" of their cattle, that is their body composition. Ribeye area and fat thickness are two traits that are highly related to retail product of a beef carcass, so that cattle going to slaughter will be graded according to these traits as well as marbling, etc.. Feeder cattle may be sorted into uniform groups based upon their fatness (Sainz and Oltjen, 1994). Cow-calf producers may implement supplementation strategies based upon cow condition, either assessed visually or by ultrasound. Seedstock producers may use composition data in their selection programs, since fat thickness and ribeye area are moderately to highly heritable. All of these are examples of real benefits to be gained from knowledge of cattle body composition.

Body condition has traditionally been evaluated by look and feel, and this approach is still very useful today. This is especially true in situations that require relative, non-quantitative assessments. On the other hand, when actual backfat (for example) must be known, ultrasound technology has become the method of choice. Ultrasound technology was developed originally for the medical field but has since been applied to livestock production. In fact, the Beef Improvement Federation (Bailey, 1996) has included recommendations for collection of ultrasound data in breeding stock. EPDs calculated from ultrasound data could be available in the Fall 1999 Angus Sire Evaluation. This technology depends upon the emission of sound waves and echo detection, similar to the principles underlying sonar. The instrument is laid upon the animal's back, and emits sound waves in the ultrasound frequency (usually 3.5, 5, or 7 MHz). The sound waves travel through the skin and underlying tissues, and bounce back (echo) as they hit the interface between one tissue and the next. Therefore, at the 12th rib they would travel through the skin and hair, the subcutaneous (back) fat, the loin (ribeye) muscle, and then bone (if positioned over a rib). Each of these interfaces would produce an echo, which the instrument converts into an image (Figure 1).

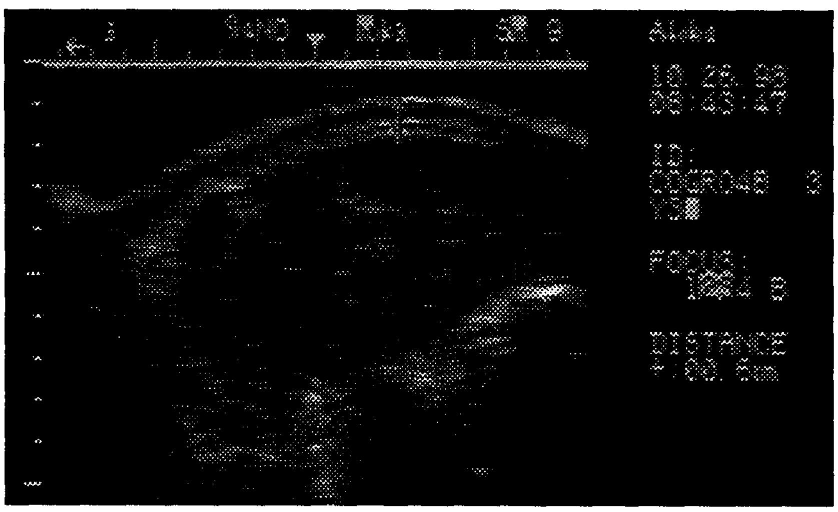


Figure 1. Ultrasound image of backfat and ribeye of a feeder steer.

According to the BIF (Bailey, 1996), yearling bulls should be scanned at the end of a production gain test, to allow the maximum potential for the bulls to express their genetic differences for external fat cover, rib-eye area and intramuscular fat percentage (marbling). Fat thickness is measured between the 12th and 13th ribs. The measurement point is located 3/4 of the distance from the chine end (medial end) of the longissimus dorsi muscle to the lateral end. Rib-eye area is measured between the 12th and 13th ribs. This requires collecting a real-time ultrasound image using a wave guide that fits the curvature of the animal's back and the transducer. The characteristic fat dip on the top side of the rib-eye (sometimes referred to as the "acorn" fat) is not included in the rib-eye area. The amount of intramuscular fat percentage is also measured in a region of the 12th and 13th ribs. Heifers should also be scanned at a time that will allow the maximum potential for them to express their genetic differences for external fat cover, rib-eye area and intramuscular fat percentage (marbling). This may mean scanning the heifers just prior to breeding, for example at 14 to 15 months of age, but more research is needed to determine the optimal time for heifer measurement.

Work at UCD and elsewhere has shown that ultrasound can be used successfully to improve nutritional management of cows, calves and feedlot steers (Sainz and Oltjen, 1994; Sainz et al., 1995). In this case, as with genetic evaluation, ultrasound can provide additional information to aid in management decisions. In today's beef industry, information has a real economic value, and ultrasound can be a tool for adding value to cattle.

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Vegetation/Residual Dry Matter Monitoring

Bill Frost, Natural Resource Advisor
UC Cooperative Extension

Monitoring the amount of residual dry matter (RDM) present on a site is a valuable tool in ensuring sustainable forage production on hardwood (annual) rangeland. Residual dry matter, generally measured in the fall, is the dead plant material remaining from the previous growing season. That is, it is the dead, dry, yellow or brown grass, forbs and legumes left standing or lying on a site. The concept underlying residual dry matter recommendations is that if an "adequate" amount of RDM is present at the time of the first fall rains the soil will be protected from erosion, a favorable micro-environment will be present for optimum seedling establishment and growth, and sufficient organic matter will be incorporated into the soil to maintain soil fertility and water holding capacity. It has been shown that, in many areas, leaving a moderate amount of RDM will result in higher forage production the following growing season than leaving too little or too much RDM.

Residual dry matter recommendations vary according to geographical, precipitation, and soil considerations. In general, the UC Sierra Foothill Research and Extension Center uses a standard of 750 pounds per acre. In other areas, a different recommendation is use for gentle slopes and for steep slopes. To monitor whether these levels will be met, the standing amount of vegetation can be measured late in the previous growing season. While we have begun a study to determine the percent of the standing crop that will break down over the summer, with no grazing, a general assumption can be made that about 30% of the standing crop will break down. Therefore, if the standing crop during at the end of grazing during the green forage period is 30% above the recommendation, the targeted amount will probably be reached.

Residual dry matter can be monitored in a variety of ways. The easiest is to use a set of photos, such as those presented in *Guidelines for Residue Management on Annual Range* (UC Leaflet 21327). Three photos are presented, showing situations with too little, too much, and a moderate amount of RDM. The moderate photo is described as having a patchy appearance with little bare soil showing. The most direct approach, but also the most time consuming, is to clip (harvest) several plots and weigh the amount of material remaining. This is a useful tool to the uninitiated, as it provides excellent training for ocular estimates of RDM. Ocular estimates, following training such as clipping plots, is the most commonly used form of RDM monitoring. Other, more technical methods, such as double sampling methods (comparative yield for example) are also available, and produce accurate measures of RDM.

Recording this information on maps will allow managers to see the pattern in which livestock are utilizing a pasture. With this information management changes can be made to use underutilized areas and reduce use on areas which are being over utilized. These changes can often be made as simply as moving supplemental feeding locations or moving water troughs. By managing to leave moderate amounts of RDM on a regular basis, the base amount of forage produced on a yearly basis will be increased, and the potential for soil loss decreased.

Photo Monitoring

Glenn Nader

It is often said that a picture is worth a thousand words. Photographs taken consistently over the years provide an easy, convenient, and inexpensive method by which ranchers can establish a visual representation of resource conditions. You can use photos to supplement transect data and to present data to audiences of varied backgrounds. Although most call photo monitoring only qualitative, it is something that a rancher may have time to get done. Clipping forage and weighing it to obtain quantitative numbers of residual dry matter is good, if it every gets done. There are two basic types of monitoring pictures: landscape photographs and close up photographs. You should consider using both types when monitoring.

Landscape Photographs

Landscape photographs document change over time. Try to find old family or ranch photographs that show historical vegetation conditions. These historical photos provide you with previous range conditions. New pictures from the same locations allow you to immediately illustrate vegetational changes.

Landscape photos should be taken from the same designated point (marked by a steel post or other type of permanent marker). The steel post may be placed to direct by the use of a compass the position of the camera for the photo. Include a distinctive landmark in the background (peak, rock outcrop, tree, etc.) or another steel post set 20 feet away to line up on for the photograph. A compass direction and previous photographs are helpful in lining up photographs in subsequent years.

Close-Up Photographs

Close up photographs show specific characteristics of an area such as soil surface, ground cover by vegetation, and organic litter. Permanent photo plots can be marked by angle iron or rebar. You should paint the stakes with a bright colored spray paint for ease of locating the plot in subsequent years. You may mark the plot in the photograph by using two 6-foot folding rulers, or a 3 x 3 foot square made of PVC pipe that is distinctly marked in 1- inch increments on at least one side, (see page 23 for PVC instructions). The folding ruler or PVC pipe helps illustrate plant density and scale in the photograph. A non-white photo ID card (see, Appendix II) showing date, photo point number, and the allotment/pasture should be placed flat on the ground on the outside edge of the plot. Make sure that the ID card is included in the picture. A witness post may be placed by the road with a corresponding compass bearing in order to locate the witness post at the photo point (plot). Take the picture from the north side of the plot by standing over the plot without casting a shadow on the plot, and with your toes touching the edge of the plot. Consistency in taking pictures from the north side of the plot prevents a shadow from being cast on the plot. Use three different size balls, such as softball, tennis, and golf ball at the end of the grazing season to indicate the residual dry matter left on the site.

When to Monitor with Your Camera
No matter when you choose to monitor you should be consistent from year to year. The exact day is not important since seasonal conditions vary from year to year. Instead, try to time your monitoring to correspond to a stage of growth of a particular plant (i.e. the heading out of cheatgrass, the flowering of bitterbrush), or before and after grazing (on and off dates). Monitoring after grazing has the advantage of documenting the amount of forage left.

After developing the slides or photographs write information (date, pasture/allotment) on the edge of the slides. If photographs are stored in a photo album, place adhesive labels (Appendix I) on the back describing the location, date, etc. Place slides or photos in a binder using photo or slide storage sheets that are **non-pvc, non-acidic** to protect them from damage.

Analyzing Your Photos
Landscape pictures are generally classified as qualitative data. Dramatic changes are clearly evident over time. Subtle changes may require in-depth study of landscape photos to ascertain if a change has occurred and what direction the change may be headed. Close-up photos can be used either as a qualifying or quantifying measurement of the direction of the resource. If slides are used, you can project the image on a paper background and trace bare soil in the plot and calculate the area of which it encompasses. This can also be done with enlarged prints, but with less detail. New computer technology is being investigated to see if a system for analysis of photos can be developed. Remember to review your goals and see if the changes in the rangeland resource depicted in your picture are moving you closer towards achieving your goal.

<u>Three Foot PVC Photo Plot Frame Materials List</u>

4 -- 35.5" lengths of 1/2 inch schedule 4- PVC pipe (Total required = 144" or 12 feet).

4 -- PVC 1/2 inch schedule 40 90° elbows.

Electrical tape -- 1 inch wide, to mark 1" intervals on 2 sides of the PVC pipe frame.

UPDATE ON YELLOW STARTHISTLE CONTROL

Mike Connor, Glenn Nader and Tammy Karnow

CHEMICAL CONTROL

Roundup Ultra can be used on pastures for yellow starthistle control after most desirable annual plants have matured and set seed, but before starthistle has flowered. It should be applied at the time the first yellow flowers appear. Then no viable seeds will be produced, as the nutrient flow to the seed head will have been broken. Roundup is most effective for spot spraying of relatively small areas of infestation. The recommended rate is one pound of active ingredient per acre or a 1% solution. At that rate, the cost for material is approximately $12 for each acre actually sprayed. For spot spraying, this would be spread over several acres of a larger field. Our cost of application for spot spraying is about $10 per acre.

2,4-D is an effective control agent if administered after most yellow starthistle plants have germinated, but before flowering has occurred. It can also be applied earlier, but repeat applications are necessary because starthistle germinates over such a long time period. If application is made after germination, most starthistle will have bolted. At the point, 1½ to two pounds per acre of active ingredient (1½ to two quarts of material) is necessary for control. At two pounds per acre the chemical cost is $7.50 per acre.

Transline has proven to be a herbicide that can totally control yellow starthistle during the year of application. Starthistle germinates throughout the fall, winter and spring, and even in summer if moisture is available. Transline is successful because it provides both pre- and post-emergence control and, thus, season-long effectiveness. Transline is a selective herbicide. Susceptibility is limited to certain broadleaf plants, especially thistles and some other members of the composite family. Many legumes, including annual clovers, burclover, medics, and vetch, are susceptible. Grasses and filaree are not harmed, nor are most weedy mustard species or fiddleneck.

Several trials at Sierra Foothill Research and Extension Center have shown the value of Transline against yellow starthistle. On January 21, 1998, we applied 1/4 pint of Transline per acre to research plots in field P2-41 using a field sprayer. In June we counted the species present and clipped and weighed the amount of dry vegetation. Transline had completely eliminated yellow starthistle. In contrast, in the control plots about 2300 pounds per acre of starthistle was produced (Table 1). Even a low rate of 1/8 pint per acre in a plot in field H-9, sprayed on March of 1997, reduced starthistle to less than one percent composition the following June. Research by Glenn Nader in Butte County, UCCE Weeds Specialist Joe DiTomaso and others has also demonstrated the effectiveness of this herbicide.

Transline is registered for use on rangeland in California at between 1/4 and 2/3 pint (4 ounces and 10.8 ounces) of product per acre. The recommended rate for this area is 1/4 pint. It should be applied in January or February before the plant bolts and before surrounding grasses grow to more than four inches in height. During late years, such as the current one, successful application can be made into March. No surfactant needs to be added to the mix if spraying occurs before starthistle bolts.

Transline can be purchased in 1 gallon containers at a cost of about $400 or in 2 ½ gallon containers at $350 per gallon. Thus, at the recommended rate the material cost is about $11 per acre. Aerial application by helicopter can be obtained for around $15 per acre depending on amount of acreage sprayed, terrain and location. Aerial application by fixed wing aircraft, where appropriate, would be less expensive. We estimate the cost of ground application, where topography allows, at $9.00 per acre.

OTHER CONTROL METHODS

Rose clover seeding. Dan Drake, in Siskiyou County, and others have had some success in planting rose clover in yellow starthistle-infested rangelands to provide competition. Fred Thomas used several varieties in a plot at SFREC which did a good job of crowding out starthistle. We planted Hikon rose clover in the H-9 plot in November, 1996. We either disced or harrowed in the seed, and followed it with 300 pounds per acre of 18-46-0 fertilizer containing 18 % sulfur. The 1996-97 growing season was not good for clover, and we did not get a good stand the first year. Apparently, hard seed carried over and germinated and grew successfully in 1997-98, a season which was more suitable to clover growth.

In July of 1998, the second summer following planting, the plots were compared for the percent composition of important species. The results are shown in Table 2. The clover did not grow uniformly throughout the plot, but in 1998 clover composition was significantly higher in the seeded plots (30% in disced and 15% in harrowed vs. 9% for the control). Yellow starthistle composition at about 25% in the two clover plots was significantly lower than the level in the control plots, although a 25% starthistle population is still considerable and sufficient to reseed the area.

Transline is known to be harmful to most annual legumes including rose clover. As shown in Table 2, even the low rate of Transline administered in 1997 reduced clover composition the following year (approximately 2% vs. 9% for the control), and the high rates utilized in 1998 essentially eliminated the clover in 1998.

Discing did not consistently reduce subsequent yellow starthistle levels in this study. It did significantly lessen composition of the weedy annual grass medusahead. The analysis showed that all of the disc treatments were lower in medusahead composition than the non-disc treatments (Table 2). These effects were evident through all replications. This is understandable because medusahead composition is known to decrease due to disturbances such as discing, heavy grazing or fire.

Because of a significant difference in medusahead composition among the replications, this trial cannot confirm or deny the suspicion that removal of starthistle results in its replacement by medusahead. In this trial, any such effect depended more on the characteristics of the location, such as soil type and plant species composition prior to start of the trial, than on the removal of starthistle.

Mechanical control can be accomplished by detaching starthistle plants at ground level by hoeing, hand pulling, and by hand-held weeders. Mowers can not sever the shoots this low because they cut at a height of three to four inches. Field studies were conducted in five northern California counties to examine the effects of growth form, timing of mowing, and number of mowings on yellow starthistle growth and seed production. If a mower can cut below the first branch on the stem of a starthistle plant, at early flowering (2 to 3 % bloom), mowing can effectively reduce starthistle seed production and growth. In areas with a significant annual grass population, starthistle growth form becomes more erect with a higher branching pattern and little, if any, basal foliage. Under this condition, mowing provides an effective technique for suppression of yellow starthistle. Erect, high-branching populations were effectively controlled by a single mowing, while low branching plants were not satisfactorily controlled even by multiple mowings.

Fertilizer alone and in combination with Transline was studied in 1998 in a trial in the P2-41 field. The fertilizer was a liquid, containing nitrogen (20%) and phosphorus (10%), which could be tank mixed with Transline. The Transline rate was 1/4 pint per acre; 100 pounds per acre of fertilizer was applied. Both materials were applied January 21, 1998 by a ground operated sprayer. The plots were harvested June 1, 1998 and the percent composition and dry matter yield of yellow starthistle, grass and other forage were analyzed. The results are shown in Table 1. This research demonstrates the effectiveness of Transline in controlling yellow starthistle and that fertilization of starthistle-infested rangelands without weed control is not productive.

Controlled burning has been shown in research by DiTomaso to be successful at eliminating starthistle populations if done properly. Burning must take place in the summer when the target weed is in early bloom, and adequate residual dry forage must be present to carry a fire hot enough to kill the plant and destroy the seed heads.

LONG TERM CONTROL

Work by DiTomaso in California and researchers in other states indicates that the seed bank from a dense yellow starthistle population remains viable for about three years. Thus, any control measure must continue for more than one year for long term results. Application of Transline for a number of years will clearly control yellow starthistle. However, it is expensive and has the potential to increase composition of objectionable species such as medusahead, it will reduce annual legume populations, and there is a possibility of plants developing a resistance to the chemical. Research is continuing into how many years of broad scale chemical control is necessary and toward finding ways of integrating other control methods, including prescribed burning, into a management plan.

Transline does not persist at high enough levels into the following season to provide effective control, but there has been some apparent carryover effect in our plots from the previous year's treatment, presumably due to a significant reduction in the seed bank. In the H-9 plots, even the low rate of Transline applied resulted in approximately a 50% reduction of starthistle composition in 1998 in plots which were treated in 1997 but received no treatment in 1998. As seen in Table 2, the 1997 Transline plots averaged about 22% starthistle compared to 43% for the control. It should be noted that while this is a significant reduction, the level of starthistle remaining will result in adequate seed production to rebuild a dense stand in subsequent years.

We are using both the H-9 and P2-41 plots to further study any carryover effects from treatment with Transline the previous year. We are currently looking at carryover from the high rates (two and three times the recommended) applied in H-9 and the recommended rate administered in P2-41. Both of these applications made in1998 achieved excellent control in the year of application, as seen in Tables 1 and 2. Starthistle composition will be compared in plots receiving the recommended rate this year, no treatment this year following treatment the previous year, and controls (no current or previous treatment). Percent composition analysis was conducted in April and will be done again in June, 1999. Dry weight of important species categories will be determined at peak standing crop.

DiTomaso has established a trial this spring which will study the results of two years' treatment with Transline and integrating prescribed burning with Transline on alternate years. We have also initiated a trial which will look at the effects of three years of Transline treatment compared to controlled burning during one of the first two years. It will be done at a field scale with moderate cattle grazing, so the results should apply to typical grazed rangeland.

SUMMARY

Several chemicals can be used in yellow starthistle control. Roundup provides good control when sprayed after desirable annual plants have matured. It is relatively expensive, but may be used for cleanup of starthistle in smaller areas. 2,4-D amine is effective at two pounds per acre after germination has occurred, but before flowering. Even at the relatively high rate, it is cheaper than other chemicals. Transline at 1/4 pint per acre appears to be a very successful chemical for control of yellow starthistle because its pre- and post-emergence activity gives it a long period of effectiveness.

Long term control depends on reducing the seed bank over several years. More than one control method may be used to accomplish this. We are looking at alternating prescribed burning with chemical control and examining the number of years that treatments will be necessary in order to achieve the desired long term reduction in yellow starthistle populations.

Table 1. TRANSLINE AND FERTILIZER STUDY

Average Dry Matter Yield in Pounds per Acre of Species Categories, June 1998

Species category	Transline + fertilizer	Transline	Fertilizer	Control
Yellow starthistle	0 a *	0 a	2332 b	2294 b
Grass	2006 a	1910 a	921 c	1315 b
Total Non-YST forage	2525 a	2246 a	1267 b	1584 b

* Values in the same row followed by different letters are significantly different.

P2-41 Trial. The trial was established to test the effects of Transline, fertilizer and the combination of Transline and fertilizer on yellow starthistle populations. We are now using it to examine the effects of treating with Transline in alternate years. Twelve by 75 foot plots were established on January 21, 1998 in an area moderately grazed by cattle and last grazed in February, 1996. The plot area had a relatively uniform, moderately dense stand of yellow starthistle. Four treatments were randomly assigned through three replications.

Table 2. H-9 STARTHISTLE CONTROL STUDY

Average percent composition of important species, July 1998

Treatment	Starthistle	Rose Clover	Medusahead
Annual ryegrass, disced in, fall 1996	49 a *	8 c	8 cd
Control	43 b	9 c	19 b
Annual ryegrass, harrowed in, fall 1996	36 bc	0.5 d	30 a
Rose clover, harrowed in, fall 1996	29 cd	15 b	15 bc
Transline, 1/8 pint, applied in 1997	25 d	1.5 d	20 b
Rose clover, disced in, fall 1996	22 d	30 a	3 e
Transline, 1/8 pt., 1997, following discing	19 d	2 d	10 cd
Transline, 1/4 pint, applied in 1998	0 e	.02 d	32 a
Transline, 1/4 pint, applied in 1998	0 e	0 d	18 b

* Values in the same column followed by different letters are significantly different.

H-9 Trial. The trial was established to quantify the ability of different practical methods to control yellow starthistle . The 15 by 50 foot plots were established on November 1, 1996 and fenced to exclude cattle. Grazing is only allowed each fall after observations of the plot are completed. The plot area had a relatively uniform moderately dense yellow starthistle stand. Treatments were organized in a complete randomized block design with four replications.

Evaluation of Buffer Zones to Attenuate Nutrient and Sediment Transport from Irrigated Pastures

Glenn Nader, Kenneth Tate, Michael Conner, Barbara Allen-Diaz, Edward Atwill, and David J. Lewis.

Regulatory, land management, and municipal water agencies are considering the use of buffer zones to eliminate the risk to water quality from livestock on rangelands. This study quantifies nutrient and total suspended solids levels in runoff and evaluates the effectiveness of 30 foot buffer zones for attenuating these constituents from hill slope pastures in the northern Sierra Nevada Foothills.

Methods

The study was conducted on flood and sprinkler irrigated foothill pastures at the University of California Sierra Foothill Research and Extension Center (SFREC) located near Browns Valley in the northern Sierra Nevada foothills. Each pasture used in this used was managed according to common practice including moderate grazing and prescribed fertilization and irrigation. Four field sized plots were constructed in each pasture and treatments were replicated twice per pasture. Treatments were 0 (unbuffered) and 30 feet (buffered) buffer strips applied to plots located within the flood and sprinkler irrigated pastures. Plot size ranged from .5 to 1.5 acres. Buffers were established by fencing the lower 30 feet of a plot, adjacent to the stream channel or tail water ditch. Tail water runoff volume, tail water samples and irrigation water samples were collected from each plot during nine irrigation events during the summer of 1997. Runoff volume was measured at a 0.25 hr time step using an electronic stage recorder at a 1 ft V-notch weir. Tail water samples were collected on an hourly basis with automatic water samplers. Irrigation water samples were hand collected at the start and end of irrigation. Water samples were analyzed for N03-N, Total P, and TSS. Statistical analysis included analysis of variance (ANOVA) tests for differences in mean concentrations and loads for buffered and unbuffered field tail water. Regression analysis was made for N03-N, Total P, and TSS against tail water discharge and time sampled during each irrigation event.

Results and Conclusions

Observed tail water concentrations for N03-N were below USEPA drinking water standards of 10 mg/i (USEPA, 1996). At present there are no standards for Total P, and TSS. Comparing concentrations from unbuffered and buffered fields, we found no significant differences between buffered and unbuffered N03 or Total P concentrations in irrigation tail water from both flood and sprinkler irrigated pastures. TSS concentrations from both flood and sprinkler irrigation were statistically lower with a 30-foot buffer than with no buffer. Results from load comparisons found no significant differences for N03-N, Total P, and TSS loads between unbuffered and buffered tail waters from both flood and sprinkler irrigated pastures. These results indicate that buffer strips, at this location, do not have the expected best management practice benefits and furthermore that water quality from hill slope pastures is benefitted by other management practices.