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**Research Brief #10**

# Food Safety versus Environmental Protection on the Central California Coast: Exploring the Science Behind an Apparent Conflict

*– Diana Stuart,[1] Carol Shennan,[2] and Martha Brown[3]*

The September 2006 outbreak of *Escherichia coli* O157:H7 traced to Salinas Valley spinach has spotlighted problems with food safety on Central Coast farms and in food processing facilities. This is not the first time the Central Coast has been in the food safety spotlight: nine other *E. coli* outbreaks have been traced to lettuce and leafy greens from the region in the past decade. Although it is important to note that 90% of pathogenic *E. coli* contamination events are traced to meat products (see sidebar, next page), produce-based outbreaks place enormous pressure on growers to limit or eliminate potential sources of contamination from their farming and processing operations.

At the same time, Central Coast growers face regulatory mandates to limit pollution originating from fertilizers, pesticides, and erosion sources. Coalitions of growers, government, and non-governmental organizations have worked hard to put in place "best management practices" using non-crop vegetation such as filter strips, vegetative barriers, contour buffer strips, grassed waterways, and constructed wetlands designed to minimize the impacts of agricultural pollutants on adjacent waterways and wetlands.

This research brief examines the way that pressures on growers to achieve both food safety and environmental protection are connected—and may be on a collision course. Growers who have recently adopted practices to minimize water pollution may now face pressure to eliminate these conservation measures in order to meet industry guidelines that call for "clean" fields in the name of food safety; such guidelines aim to minimize the presence of wildlife, seen as a potential disease vector. This raises the specter of Central Coast farmers having to remove non-crop vegetation for some distance around their fields, greatly increasing potential losses of nutrients, pesticide residues, and sediment, not to mention the loss of biodiversity and habitat for beneficial insects and birds.

Using information from existing research, we explore the question: Are the goals of environmental protection and food safety mutually exclusive on the Central Coast, or can we have safe food and a healthy environment? To do so we examine efforts by growers, government, and non-governmental organizations to address environmental problems in Central Coast counties, and the effectiveness of these measures at reducing pollution. We then summarize the history of food safety issues and outline potential sources of crop contamination in the field. Finally, we discuss the ways that food safety guidelines conflict with environmental protection methods, and propose the idea that such methods could in fact reduce contamination sources and improve food safety.

## BACKGROUND

Encompassing Monterey, San Benito, Santa Cruz, San Mateo, and San Luis Obispo Counties, the Central Coast is one of the most productive and profitable agricultural regions in California, providing high-value specialty crops to consumers nationwide. Central Coast growers produce over 200 types of crops, generating up to five billion dollars annually. Monterey County's Salinas Valley, known as the "Salad Bowl" of America, produces up to 82,000 tons of lettuce each year. Other specialty crops grown in the region include strawberries, artichokes, broccoli, and spinach.

Intensive row crop production brings with it the potential for environmental impacts on natural resources, including streams, rivers, and wetlands. Working with government agencies and non-governmental organizations, Central Coast growers have responded to mandates to reduce the deposition of nutrients, pesticides, and sediment into waterways and sensitive ecosystems. Specific practices—most of which use non-crop vegetation to absorb and filter out pollutants—have been designed to reduce impacts of these agricultural pollutants.

Along with environmental challenges, the other, highly visible issue facing Central Coast growers and food processors is reoccurring problems with food safety. The most recent outbreak of *E. coli* 0157:H7 in September 2006 was associated with spinach from the Salinas Valley. The outbreak led to 3 deaths and sickened more than 200 people in 25 states and Canada, prompting the removal of both fresh and bagged spinach from grocery shelves and restaurant menus nationwide.

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Growers have been trying to address all possible sources of contamination. The agricultural industry is already using food safety guidelines created by industry groups and third party auditors to guide growers in eliminating *E. coli* 0157:H7 sources from the fields. There is increasing pressure to turn these guidelines into mandatory regulations.

However, various industry guidelines currently conflict with environmental practices by encouraging growers to remove any non-crop vegetation that could attract wildlife, viewed as possible disease vectors. Non-crop vegetation is a key component of current strategies to address regional water pollution.

Before current food safety guidelines are further adopted or become mandatory, it is important to evaluate their full impact. Removing environmental practices would not only reverse progress towards addressing water quality issues, but could also potentially increase the presence and transport of pathogenic bacteria.

### Meat Is the Major Culprit in *E. coli* O157:H7 Outbreaks

Certain strains of *E. coli* bacteria normally live in the intestines of cattle, wildlife and humans causing no harm. The O157:H7 strain became known in 1982 as a result of an outbreak associated with hamburger meat. It causes severe diarrhea and can lead to kidney damage and even death. Young children and the elderly are particularly vulnerable.

An estimated 73,480 illnesses occur each year in the United States due to *E. coli* O157:H7 resulting in an estimated 2,170 hospitalizations and 61 deaths (Mead et al. 1999). Most of these outbreaks are traced to the consumption of contaminated meat, which is usually infected during the slaughtering process.

Consumption of ground beef is the most common vehicle of food borne *E. coli* O157:H7 outbreaks: 41% of food borne outbreaks are from ground beef, whereas 21% are from produce (Rangel et al. 2005). Almost half of all produce contamination occurs during food preparation due to cross contamination with contaminated meat or other foods in the kitchen (Rangel et al. 2005).

## CENTRAL COAST COMBINES INTENSIVE FARMING, FRAGILE HABITATS

Water quality problems on the Central Coast stem in part from the presence of intensive agriculture in an environmentally sensitive setting. The area juxtaposes fertile soil and a climate ideal for year-round cultivation with an extensive network of coastal waterways and wetlands supporting unique plant and animal communities. The watersheds of the region, including those of the the Pajaro River, the Salinas River, and Elkhorn Slough, empty into the Monterey Bay National Marine Sanctuary, the largest marine protected area in the United States. Elkhorn Slough is also one of the largest remaining tidal wetlands in the US (NOAA 1999). Approximately 75% of the land surrounding these watersheds is used for agriculture (State of California 1997).

The waterways entering the marine sanctuary have repeatedly failed to meet water quality standards due to significantly elevated levels of nutrients, pesticides, and sediment (Caffrey et al. 2001, Hunt et al. 1999). Since agriculture in the area is dominated by vegetable and strawberry production, the region is especially prone to nutrient runoff. Vegetable systems are more likely to result in nutrient leaching due to frequent cultivation, relatively short periods of growth, and lower nutrient uptake efficiencies (Di and Cameron 2002). In addition, the climate in the Central Coast can increase the extent of nutrient discharge: accumulated nutrients in the summer and fall are washed into waterways during the first rain events of winter.

Nutrient run-off can result in excessive plant and algae growth, leading to eutrophication and degradation in aquatic and marine ecosystems. Sedimentation in runoff is especially harmful to threatened and endangered Steelhead and Coho Salmon found in the region. In addition, the presence of pesticides in waterways has been linked to declines in amphibian populations throughout California, including the federally threatened red-legged frog found in the Central Coast region (Davidson et al. 2001, Davidson 2004). Overall, pollution associated with agriculture in the region is harmful to terrestrial, aquatic, and marine ecosystems as well as humans if ingested.

## COOPERATIVE EFFORTS ADDRESS POLLUTION PROBLEMS

For the past several decades, government and non-governmental organizations on the Central Coast have been working with the agricultural in-

Paul Zaretsky

**Row crop agriculture and grazing operations surround Elkhorn Slough, one of the largest remaining wetlands in California. Slough waters drain into the Monterey Bay National Marine Sanctuary. Due in part to agricultural activities, these waters have repeatedly failed to meet water quality standards.**

dustry to address water pollution issues. Conservation programs run through the US Department of Agriculture Natural Resource Conservation Service (NRCS) offer technical and financial assistance and encourage growers to adopt environmental practices to reduce erosion and improve water quality and wildlife habitat. These practices include installing filter strips, vegetative barriers, contour buffer strips, grassed waterways, and constructed wetlands (see sidebar, below). According to the NRCS, these practices improve water quality by reducing erosion and removing organic matter, metals, pesticides, nutrients, fertilizers, and animal wastes from agricultural run-off. Although the effectiveness of such modifications is site and design specific, their adoption is considered the best way to reduce possible environmental degradation from agricultural activities.

Pressure on growers to reduce agriculturally-related water pollution increased in 1987, when Congress amended the Clean Water Act and established in section 319 the "Nonpoint Source Management Program," recognizing the need for leadership to address non-point source (NPS) pollution.[1] This program provides support for states to establish their own efforts to address NPS pollution.

**Native grasses planted adjacent to a water and sediment control basin located near Elkhorn Slough help capture sediments and pollutants from nearby agricultural operations.**

Cheryl Lambert, NRCS

In California, the State Water Resources Control Board and nine Regional Water Quality Control Boards (RWQCB) administer the NPS program. Because agriculture is the leading source of NPS pollution in the state, almost all of the program resources focus on addressing agricultural pollution. The Central Coast RWQCB has developed a program that includes grower education efforts and increasing the use of the same practices supported by the NRCS.

### Vegetation-Based Practices Used to Improve Environmental Quality

**Filter strips:** Areas of vegetation for removing sediment, pollutants, and organic matter from run-off water. This occurs through filtration, deposition, infiltration, and decomposition of materials before they enter effluent water flow. Filter strips are recommended along field edges, waterways, and around livestock areas to reduce pollution (NRCS 2006).

**Vegetative barriers:** Permanent strips of dense vegetation that cross major flow areas, reducing erosion, managing water flow, and trapping sediment (NRCS 2006).

**Contour buffer strips:** Narrow strips of permanent herbaceous vegetation that reduce erosion, facilitate sedimentation, and reduce the transport of contaminants (NRCS 2006). They can be used within or along the edges of fields.

**Grassed waterways:** Natural or constructed channels with established vegetation. Grassed waterways are designed to convey runoff, to reduce overall erosion, and to improve water quality (NRCS 2006).

**Constructed wetlands:** Wetlands designed to treat surface runoff and wastewater from livestock operations and agricultural fields. Constructed wetlands reduce the concentrations of metals, pesticides, nutrients, fertilizers, and animal wastes and also provide wildlife habitat (NRCS 2006).

Thanks to the efforts described above, growers on the Central Coast are among the most active in the state in addressing regional environmental problems. Many government and non-governmental organizations now work closely with the agricultural industry to protect waterways and biodiversity in the region.

The Agriculture Water Quality Alliance is an example of this cooperative approach to water quality improvement. Created to protect the Monterey Bay Marine Sanctuary, it encourages growers to promote environmental stewardship by providing educational programs, consulting services, and research efforts. The organization is a partnership amongst the marine sanctuary, six county Farm Bureaus, the NRCS, six Resource Conservation Districts (RCDs), and the University of California Cooperative Extension. More recently, the Central Coast RWQCB has been further developing its NPS program, which requires growers to enroll in education programs and watershed monitoring. There are approximately 2,500 growers in the Central Coast region, and about 438,000 acres of irrigated farmland. According to the RWQCB, approximately 800 growers have completed 15 hours of water quality education, and almost all growers have at least one management practice in place to reduce runoff and/or water pollution.

## EFFECTIVENESS OF NON-CROP VEGETATION IN REDUCING WATER POLLUTION

No single practice can solve the problems of diffuse sources of water pollution, therefore certain practices or

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[1] Non-point source pollution is diffuse pollution that cannot be attributed to one specific source. This contrasts with point-source, or "end of pipe" sources of pollution, which have been addressed through US environmental regulations.

combinations of practices may be best suited for specific locations depending on activities, topography, and the pollutants present. Using non-crop vegetation to "bioassimilate" pollutants is held to be the only sustainable, cost-effective, and ecologically sound approach to addressing problems of diffuse agricultural pollution (Osborne and Kovacic 1993).

According to Dabney et al. (2006) vegetative buffers such as filter strips, vegetative barriers, and contour buffer strips can retard, retain, and metabolize pollutants. Buffers restrict pollution by reducing drift, increasing sedimentation, increasing uptake by plants, and increasing microbial activity (Locke et al. 2006). Buffers less than 1 m wide can still trap significant amounts of sediment (Van Dijk et al. 1996, Blanco-Canqui et al. 2004).

Nitrogen can be retained in vegetative buffers through vegetative biomass uptake and bacterial denitrification (Haycock and Pinay 1993). A review of major studies investigating vegetative buffers indicates that nitrogen reduction ranges between 40–100% in subsurface water and between 73–98% in surface water. In the Central Coast region, nitrogen uptake may best be addressed by planting a combination of deep-rooted perennials with winter cereals that can take up nitrogen during winter rains (Los Huertos 1999).

The review mentioned above also found that phosphorous reduction by vegetative buffers ranges between 50–85% (Osborne and Kovacic 1993). Periodically harvesting vegetation can also increase phosphorous retention (Osborne and Kovacic 1993, Uusi-Kamppa et al. 2000).

Vegetation can reduce pesticide release through uptake by plants, microbial activity in the root zone of plants, extraction of contaminated water, and by reducing the movement of water through the soil (Karthikeyan et al. 2004). Vegetated buffer zones have been found to effectively remove 39–71% of pesticides from surface runoff, depending on the type of pesticide (Syversen and Bechman 2004).

Fewer studies have investigated the effectiveness of grassed waterways. However, grassed waterways have been shown to reduce runoff and sediment delivery by up to 97% (Fiener and Auerswald 2003a), and to reduce soil mineral nitrogen content by up to 84% (Fiener and Aueswald 2003b). One study found that grassed waterways can reduce agrochemicals present in runoff water by up to 56% (Brigs et al. 1999). Vegetation in waterways may be especially important for reducing pesticide concentrations: studies have shown that a greater retention and absorption of pesticides occurs in vegetated compared to non-vegetated waterways (Moore et al. 2002).

Constructed wetlands have also been studied for their effectiveness at reducing the release of agricultural pollutants. Case studies in the U.S. indicate that constructed wetlands can remove up to 68% of nitrate-nitrogen and 43% of phosphorous from agricultural drainage water (Woltemade 2000). Another study shows that constructed wetlands can reduce total phosphorous by up to 41% (Uusi-Kamppa et al. 2000). Wetlands trap sediment and nutrients, although there may be limits to the amount of nitrogen and phosphorous they can retain. Microbial actions in wetlands can also convert nitrates into harmless nitrogen gas (Schaafsma et al. 2000, Hey 2002). Efficiency of nutrient trapping depends on the rate of flow, the residence time, and the vegetation present (Zedler 2003). The vegetation in constructed wetlands may also be important for the attenuation of chemical pesticides (Milam et al. 2004).

These studies illustrate that environmental practices using non-crop vegetation in buffers, filters, and constructed wetlands within and adjacent to agricultural fields can successfully reduce levels of agricultural pollutants. The success and efficiency of pollutant attenuation is highly dependent on the specific site and design. As design standards are refined, the large-scale adoption of these practices could significantly reduce levels of pollution associated with agriculture on the Central Coast. However, the progress made introducing and encouraging the adoption of these practices could be substantially reversed due to conflicts with food safety guidelines.

## FOOD SAFETY A CRITICAL ISSUE ON THE CENTRAL COAST

Since 1995, there have been 20 outbreaks of food-borne illness from *E. coli* 0157:H7 on lettuce or leafy greens; of these outbreaks, nine were traced to the Central Coast. In 1996, a significant outbreak of *E. coli* sickened over sixty people on the East Coast and was linked to lettuce from a San Benito County farm. Contamination of lettuce or spinach from Monterey County was linked to one major outbreak in 2002 and two other outbreaks in 2003. An outbreak of *E. coli* in Minnesota in the fall of 2005 was also linked to salad mix grown in Monterey County. Most recently, in September 2006 an outbreak of *E. coli* 0157:H7 affected consumers in over 25 states, drawing nationwide attention. Food safety has become a critical issue to be addressed in the region.

There are many possible reasons for the increased occurrence of food-borne illness from fresh produce in the past several decades. Whereas produce-associated outbreaks accounted for 0.7% of all food-borne outbreaks in the 1970s, they accounted for 6% in the 1990s (Sicapalasingam et al. 2004). This could be related to the overall increase in consumption of raw fruits and vegetables (Bureau of Census 1996, Beuchat 1996), changes in human demography, microbial adaptation (Altekruse et al. 1997), and/or changes in farming or processing practices (Beuchat 2002).

Food contamination can take place at any point between the fields where food is grown and when food is consumed in the home or at a restaurant. Possible sources of contamination include improperly composted manures, irrigation water containing manure or sewage, contact with domestic animals, contact with wild animals, contaminated wash water, human handling, contaminated ice during storage, or contamination during packaging, slicing or shredding, and food preparation (Beuchat and Ryu 1997, Beuchat 2006, Tauxe 1997, Francis et al. 1999, Rangel et al. 2005).

Most of the outbreaks are due to pathogens that have animal reservoirs or *zoonoses*, i.e., pathogens that can be transmitted from animals to humans (Tauxe 1997). Although there are many different types of bacteria associated with animals, only certain strains of bacteria are harmful if ingested by humans. For example, there are many types of *Escherichia coli* (*E. coli*) bacteria found in the intestines and feces of all animals. However, only specific types of *E. coli*, such as *Escherichia coli* 0157:H7, cause illness in humans. Documented outbreaks of *E. coli* 0157:H7 have occurred from "ready to eat" and minimally processed foods such as apples, cantaloupe, sprouts, spinach, and lettuce. These foods retain a large portion of their original microflora accumulated during growth (Francis et al. 1999). Because these types of produce are often not cooked, they have a greater chance of causing food-borne illness if contaminated with pathogenic bacteria.

Approximately half of all U.S. *E. coli* 0157:H7 outbreaks from produce between 1982 and 2002 were due to contamination during food preparation; the other half were caused by contamination that occurred either in the field or during handling and processing (Rangel et al. 2005). Because *E. coli* 0157:H7 is carried and transmitted by animals, pre-harvest contamination is typically linked to animal feces from the applications of manure; cattle and domesticated animal operations; contaminated irrigation water; contaminated flood water; and direct contact with domesticated or wild animals carrying pathogenic bacteria.

### POSSIBLE SOURCES OF CROP CONTAMINATION IN THE FIELD

### *Contamination from Soil*

Crops can be exposed to *E. coli* through contact with contaminated soil (Francis et al. 1999). Fecal material from animals, especially livestock, is a major source of soil contamination, with cattle identified as the most important reservoir of *E. coli* 0157:H7 (Nielsen et al. 2004). The 2006 contamination of spinach in the Salinas Valley has been tentatively linked to *E. coli* O157:H7 in cattle manure that may have been spread by wild pigs from cattle located less than a mile from the spinach fields (Bridges 2006).

**Ready-to-eat crops such as spinach and lettuce have a greater chance of causing food-borne illness because they are often not cooked.**

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Both raw and composted cattle manure are often applied as a fertility source in farming systems, although the use of raw manure has been modified in the Central Coast region (see below). Such applications serve several purposes: they provide an alternative or supplement to synthetic fertilizers, they build levels of soil organic matter, and they provide a way to dispose of the large quantities of manure that accumulate in stockyards, feedlots, and dairy operations. However, manure can incubate pathogens and contaminate crops in the field (Natvig et al. 2002). Pathogens have been shown to be transferred from manure to the surface of crops on contaminated soil particles. Once on the surface of the crop, pathogens may persist for extended periods of time (Islam et al. 2005, Beuchat 1999).

Several studies suggest that the composition of cattle diets can affect the bacteria found in manure. Diez-Gonzalez et al. (1998) show that cattle fed grain have significantly higher levels of *E. coli* than cattle fed hay or cattle that were grazed on pasture. Another group of scientists explored the effects of different cattle diets on *E. coli* 0157:H7 and *Salmonella* in manure from dairy cattle (Franz et al. 2005). They found that manure from cattle with a pure hay diet had reduced levels of *E. coli* 0157:H7 and *Salmonella* compared to manure from cattle fed a combination of grass and maize silage. They conclude that a high starch diet favors the growth and survival of pathogenic bacteria. Because feeding grain to cattle has become a common practice, manure may now have higher concentrations of pathogenic bacteria than occurred with traditional feeding regimes. These researchers conclude that feeding cattle hay could reduce pathogen excretion and lower the levels of harmful bacteria found in manure.

Composting manure is common, and is an effective way to reduce the presence of pathogens (Jiang et al. 2003). However, the effectiveness of composting practices in eliminating *E. coli* 0157:H7 can depend on temperature, moisture, and composting time (Hess et al. 2004). Improper composting can result in crop contamination.

The National Organics Program has specific composting requirements for manure and other material used in compost; these include the need for defined carbon to nitrogen ratios, specific temperatures that must be reached during the composting process, and set lengths of composting time (NOP 2006). On the Central Coast, many conventional growers follow Good Agricultural Practices as outlined by their buyers, which involve composting or aging manure before application (Richard Smith, UCCE Monterey County Farm Advisor, pers. comm.)

Due to possible risks from manure to "ready-to-eat" crops such as lettuce and spinach, the application of raw manure has been phased out on the Central Coast. Application of aged or composted manures (if used) is usually limited to fall, to allow a substantial window of time prior to spring planting (R. Smith, pers. comm.).

Diverse microbial organisms in soil may protect crops from contamination.

One study indicates that naturally occurring bacteria in soil can reduce the abundance of *E. coli* 0157:H7 and inhibit the pathogen from uptake into lettuce tissue (Johannessen et al. 2005). Soil with diverse microorganisms may contain *Pseudomonas fluorescens*, a bacterium known to compete with and inhibit the growth of *E. coli*. 0157:H7. This study indicates that microbial pathogens may flourish in soils that lack a balance of natural microbial diversity, and that soil management should aim to encourage the diversity of microbial organisms.

Organic fields have been shown to host higher diversity and biomass of soil microbial and faunal communities that have been correlated with higher suppression of soil-borne plant pathogens (Van Bruggen 1995). This pattern may also hold for the suppression of pathogens such as *E. coli* 0157:H7.

### *Contamination from Water Sources*

Water can also transport pathogens to crops. Rivers, creeks, or streams that are diverted and used for irrigation may contain pathogenic bacteria from upstream activities, such as livestock operations. Runoff from open lot cattle grazing areas and concentrated animal operations has been shown to contain harmful pathogens (Vinton et al. 2004). Water draining from both open lot grazing operations and concentrated animal operations should be managed to prevent contaminated runoff (Koelsch et al. 2006).

Due to the possibility of water contamination from livestock or human waste, it is recommended that food crops not be irrigated with water from unknown sources and with unknown microbial content (Solomon et al. 2002). Flooding of nearby contaminated water bodies onto fields can also result in contamination of crops.

**Cattle have been identified as a major source of *E. coli* 0157:H7, which can spread from contaminated manure.**

Studies have also investigated how different methods of irrigation can affect the risks of crop contamination. One study found that lettuce is more likely to test positive for *E. coli*. 0157:H7 if exposed through contaminated sprinkler water than through contaminated surface water (Solomon et al. 2002). Another study also found that spraying crops repeatedly with contaminated irrigation water increases chances of contamination (Solomon et al. 2003).

Contamination likely occurs through direct contact between the above-ground portions of crops and contaminated water; however, studies show that if concentrations are high enough, it may be possible for *E. coli* 0157:H7 to enter crops through the roots.

One study inoculated irrigation water with extremely high concentrations of *E. coli* 0157:H7 and found that the pathogen entered the plant tissue without surface exposure (Solomon et al. 2002). However, the authors of this study admit that the concentrations of *E. coli* 0157:H7 used far exceed any that would be found on an agricultural field. Another group of scientists found that the ability for contamination to occur through the root system appears to be dose dependent, although the specific level at which this occurs is unknown (Wachtel et al. 2002a).

In a more realistic scenario, scientists investigated cabbage that was irrigated with creek water contaminated by a sewage spill (Wachtel et al. 2002b). Here, they found that although the roots were contaminated by *E. coli*, the edible portions of the plant were not. In the absence of exceedingly high concentrations of pathogens, direct surface exposure to contaminated water is the likely route of contamination.

### *Contamination from Direct Contact with Animals*

Because *E. coli* 0157:H7 originates from animals, crop contamination can occur through direct contact with animals. Domestic cattle are the primary source of microbial pathogens associated with food-borne illness.

Prevalence can vary among cattle depending on the location and the season. A study in the Pacific Northwest revealed that 3.6% of feedlot cattle and 2.3% of dairy cattle tested positive for *E. coli*. 0157:H7 (Hancock et al. 1998). Another study in England tested cattle over an entire year and found that 13.4 % of beef cattle and 16.1% of dairy cattle tested positive for *E. coli*. 0157:H7. However, in spring and summer, up to 36.8% of total cattle tested positive for *E. coli*. 0157:H7 (Chapman et al. 1997). Another study in North Dakota also illustrates that prevalence in cattle changes depending on the season and found that up to 53% of cattle tested positive for *E. coli*. 0157:H7 in the spring (Khaitsa et al. 2006).

There are also concerns that wild animals can be sources or vectors of food-borne pathogens. Research has shown that wild animals exhibit relatively low levels or an absence of of *E. coli* O157:H7. A study in the Pacific Northwest did not find any *E. coli*. 0157:H7 from 300 samples of rodents on cattle farms (Hancock et al.

1998). Rodents can be divided into two groups: field rodents and commensal rodents, such as house mice and rats (Meerburg et al. 2004). Commensal rodents may be in closer contact with humans and waste, whereas field rodents that are kept separated from these sources of contamination may have a much lower prevalence of carrying pathogens. Field rodents should be managed to minimize their exposure to livestock (Meerburg et al. 2004).

Several studies have explored the role of wild deer as vectors. In a study of white-tailed deer sharing a rangeland with cattle in Kansas, 2.4% of deer carried E. *coli* 0157:H7 (Sargeant et al. 1999). Another study in the southeastern United States found that 0–0.6% of wild white-tailed deer sharing a range with cattle showed signs of *E. coli* 0157:H7. The study concluded that wild deer are not a major reservoir of *E. coli* 0157:H7 (Fischer et al. 2001).

Many studies have investigated the possibility of birds as a source of food-borne illness. Studies in England surveyed gulls and showed that the prevalence of *E. coli* 0157:H7 in feces can range from 2% (Wallace et al. 1997) to 12.9% (Fenlon 1981). Another study in Sweden found that 4% of gulls sampled contained *Salmonella* isolates, and of 151 wild passerines (landbirds) and gulls none contained *E. coli* (Palmgren et al. 1997).

**Studies of deer have shown that they carry relatively low or no traces of *E. coli* 0157:H7, even when sharing range with cattle.**

Although most studies have looked at gulls, which are often associated with human waste, fewer studies have looked at other types of wild birds. A study of Canada Geese in New Jersey and Virginia showed no signs of *E. coli* 0157:H7 (Converse et al. 1999). A study of passerines and woodpeckers in Wisconsin showed that of 364 birds, no birds showed signs of *Salmonella* and 1% showed signs of *E. coli* 0157:H7 (Brittingham, et al. 1988). Another study in the Pacific Northwest looked at wild birds on cattle ranches and found that no birds showed signs of *E. coli* 0157:H7 (Hancock et al. 1998). These studies indicate that the presence of pathogens may be higher in birds associated with human waste, such as gulls, than in wild birds such as woodpeckers, chickadees, and nuthatches, which are associated with more natural environments.

## FOOD SAFETY GUIDELINES CONFLICT WITH ENVIRONMENTAL GOALS

Although there are currently no mandatory pre-harvest regulations to prevent contamination of crops in the field, increased awareness of food safety issues has placed considerable pressure on growers to meet high safety standards. Since it is unknown at which stage microbial contaminants are introduced, guidelines have been developed for farming practices to augment rules in place for packing, handling, and processing. The U.S. Department of Health and Human Services through the U.S. Food and Drug Administration (FDA) has produced several publications, including the "Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables" (1998) and the "Analysis and Evaluation of Preventive Control Measures for the Control and Reduction/Elimination of Microbial Hazards on Fresh and Fresh-Cut Produce" (2001). In addition, a national Good Agricultural Practices (GAP) program has created voluntary guidelines and educational material to encourage safe farming practices.

Farming organizations and private food safety auditors have developed their own guidelines. These include commodity-specific guidelines for cantaloupe and more recently for lettuce and leafy green vegetables created by cooperative efforts in the industry. In April of 2006, "Commodity Specific Food Safety Guidelines for the Lettuce and Leafy Greens Supply Chain"(Gombas et al. 2006) was released by a group of associations in the lettuce and leafy greens industry.

Although the specific causes of recent *E. coli* O157:H7 outbreaks on the Central Coast have not been pinpointed, industry-led guidelines now call for "clean" fields and many buyers insist on food safety audits to ensure that such guidelines are being followed. These guidelines and audits encourage growers to reduce the presence of wildlife and any non-crop vegetation such as shrubs and grasses that could attract wildlife, as seen in the following excerpts:

> "high concentrations of wildlife (such as deer or waterfowl in a field) may increase the potential for microbial contamination. Control of wild animal populations in the field may be difficult, especially where crop production areas are adjacent to wooded areas, open meadows, and waterways. . . . where high concentrations of wildlife are a concern, growers should consider establishing good agricultural practices to deter or redirect wildlife to areas with crops that are not destined for the fresh produce market."[2]
>
> "Evaluate the need for bare soil buffers to adjacent land that may encourage high populations of reptiles, amphibians, rodents, birds or other potential sources of contamination."[3]
>
> "Monitor and minimize domestic and wildlife activity in lettuce/leafy greens fields and production environments (e.g. reduce potential cover and har-

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[2] U.S. Department of Health and Human Services, Food and Drug Administration, Center for Food Safety and Applied Nutrition Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (October, 1998)

[3] National GAP (Good Agricultural Practices) Program

borage, eliminate standing water, utilize animal repellants and attractants)."[4]

Although wildlife are presented as a serious risk in these guidelines, the scientific studies discussed earlier do not confirm that wildlife are a significant threat. But because wildlife has been identified as a source of contamination, growers are facing pressure to remove potential habitat. This pressure to create "clean" fields places growers in a Catch-22 situation, as market-based demands to follow food safety guidelines may substantially deter the adoption of practices to address regional environmental problems, thus increasing pollution and habitat degradation.

Past and current pre-harvest guidelines have been voluntary and primarily market-driven, but with public concern over food safety increasing, the U.S. Food and Drug Administration has expressed a need to create mandatory farming standards. Recently, owners of the nation's largest supermarket chains, including Safeway, Albertsons and Ralph's grocery chains, and Costco Wholesale Corporation, have demanded that growers work with federal regulators, academia and industry research scientists to standardize food-safety requirements, including the compatible use of adjacent farmland. The grocers' consortium threatens to set up their own certification system if such standards are not quickly established and enforced (Hirsch 2006).

As industry and government personnel weigh the option of converting current industry guidelines into mandated regulations and adding additional rules for farming practices, it is critical that these guidelines be evaluated to understand the full implications of their widespread adoption, both for protecting consumer health as well as for their impact on environmental quality. If current "voluntary" guidelines become mandatory, environmental efforts in the Central Coast region and elsewhere could be substantially undermined.

Vegetated buffers of native perennial plants can filter pollutants and sediment while providing habitat for beneficial insects.

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## COULD ENVIRONMENTAL PRACTICES BE USED TO REDUCE CONTAMINATION?

Despite contradictions in current food safety and environmental guidelines, certain environmental practices may actually be useful in addressing food safety problems. Although the goal of many practices is to reduce erosion and pollution from fertilizers and pesticides, these practices can also remove and control harmful microbes. Vegetated buffers, grassed waterways, and constructed wetlands can be effective ways to reduce levels of waterborne pathogens, including *E. coli*.

Vegetated buffers can reduce the transfer of pathogenic bacteria in surface water. Contamination in overland flow may be reduced by using filtration through perennial forage and/or grasses. Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. They used known quantities of *E. coli* and measured transport in surface water runoff. Although the efficiency of filtration depends on water flow, soil type, and slope, they found that vegetative buffers are an effective way to reduce inputs of waterborne *E. coli* into surface waters. Buffers already used for environmental practices could be more specifically designed to reduce *E. coli* transport.

Grassed waterways and vegetated treatment systems within bodies of water have also been shown to reduce the presence of pathogens. Koelsch et al. (2006) reviewed studies and found approximately 40 field trials indicating that vegetative systems with a settling basin can significantly reduce pollutants, including pathogenic bacteria. Other studies indicate that fecal coliform reductions greater than 90% are regularly observed from vegetated treatment systems (Kadlec and Knight 1996). Vegetated systems may reduce the presence of pathogenic bacteria in waterways near fields and significantly reduce the possibility of contamination if flooding occurs.

Constructed wetlands can effectively reduce the presence of pathogenic bacteria and are already used in sewage and agricultural wastewater treatment. In a wetland, pathogens are removed through filtration in dense vegetation, sedimentation of particles carrying pathogens, microbial competition and predation, high temperatures, and UV disinfection (Hench et al. 2003, Nokes et al. 2003, Greenway et al. 2005). Nokes et al. (2003) show that large, as well as small-scale, constructed wetlands can reduce levels of fecal coliforms by up to 97%.

Hench et al. (2003) tested the effectiveness of constructed wetlands at removing specific pathogenic bacteria. They show that within a 23–52 hour wetland residence time *Salmonella* levels can be reduced by 93–96%. Hill and Sobsey (2001) also report a 96% reduction in *Salmonella* in wastewater from a pig farm after passing through a constructed wetland. Another study also shows that constructed wetlands can remove 95% of pathogens and indicator organisms (Greenway 2005).

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[4] Commodity Specific Food Safety Guidelines for the Lettuce and Leafy Greens Supply Chain (March 2006)

Photo by Lynn Betts, USDA NRCS

**Vegetation buffers a Monterey County wetland from impacts of an adjacent artichoke operation.**

Through their literature review, Greenway et al. (2005) conclude that surface-flow constructed wetlands with a high diversity of macrophytes can reclaim water and produce effluent meeting microbial standards for agricultural irrigation. Lastly, Nokes et al. (2003) show that heavily vegetated wetlands remove more harmful bacteria when compared to non-vegetated wetlands.

These practices, which are also used to enhance environmental quality, may be designed specifically to increase the effectiveness of reducing harmful pathogens in agricultural settings. For example, constructed wetlands can be designed to maximize the removal of pathogens (Greenway et al. 2005). With further research, design standards tailored to pathogen removal could be created for each of these environmental practices.

Ways to make the adoption of these practices more feasible can also be explored. For example, Nokes et al. (2003) show that small-scale vegetated wetlands can be equally effective and efficient at removing harmful bacteria as large-scale constructed wetlands. Given the high values of both land and crops in the region and the costs associated with construction, these small-scale wetlands as well as smaller vegetative buffers and treatment systems may be easier to apply on the Central Coast.

When assessing the overall impact of environmental practices on the safety of food, different risks must be considered. Wildlife is often blamed for outbreaks of food-borne pathogens. It is likely that the environmental practices discussed in this brief that use non-crop vegetation will attract some wildlife. However, the relative risks need to be weighed. Studies indicate that on average about 1% of wildlife associated with natural environments carry bacteria that are pathogenic for humans. If this statistic is also true for wildlife in the Central Coast, the benefits of using environmental practice to reduce contamination may outweigh possible threats from wildlife.

## CONCLUSION

With increasing pressure to address problems with food safety and the possibility of mandatory standards for farming practices, it is a critical time to evaluate the potential impact current food safety guidelines could have on efforts to improve the environmental sustainability of farming operations.

Converting guidelines calling for the removal of non-crop vegetation into regulations could represent a major setback in efforts to address water pollution on the Central Coast. However, scientific studies, such as those presented in this paper, show that the goals of safe food and a healthy environment may not be mutually exclusive. Certain environmental practices already used to reduce pollutants associated with agriculture may also be used to contain and absorb harmful pathogens. More research is needed to identify the effectiveness of these practices in addressing food safety issues specific to the Central Coast.

Some fear that the use of environmental practices may increase the presence of wildlife near cropped fields and that wildlife represent a significant threat to food safety. However, studies in other regions of the US illustrate that wildlife, such as birds and small mammals, are usually not hosts of pathogens associated with food-borne illness. To resolve these issues confidently, additional research may be needed to investigate the role of wildlife as vectors of pathogens in the Central Coast.

Some of this research is already in the works: in a current USDA-funded study, crews will collect thousands of samples of domestic animal and wildlife droppings; creek, ditch and irrigation water; and farm soil and lettuce growing on Salinas Valley farms in an attempt to identify sources of *E. coli* O157:H7. Data collected in the field will be carefully analyzed to identify the vertebrates that are sources of *E. coli* O157:H7, assess the climate, landscape attributes and irrigation management practices that are correlated with increased risk of contamination, and determine whether contaminated lettuce is associated with certain farming practices or environmental factors (University of California Agriculture and Natural Resources 2006).

Despite the need for additional research, the studies presented in this brief suggest that the goals of environmental protection and safe food can both be achieved on the Central Coast. Current food safety guidelines may be exaggerating the role of wildlife and unnecessarily pressuring growers to remove non-crop vegetation intended to improve water quality. The widespread removal of this vegetation would substantially set back water quality efforts and increase pollution in agricultural watersheds. In addition, studies indicate that these non-crop vegetation measures could also be removing and reducing the presence of pathogenic bacteria, such as *E. coli* O157:H7, in agroecosystems. Their widespread removal could actually increase risks of crop contamination.

Before further steps are taken toward mandatory farming standards that emphasize "clean" fields, it is critical that industry leaders, conservation organizations, and government agencies work together, using all available information, to resolve current conflicts and create workable solutions to both the food safety and environmental issues that currently challenge Central Coast agriculture.

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