United Fresh
PRODUCE ASSOCIATION

# Statement of Principles and Policy Support For Strong, Federal Oversight of Produce Safety

**May 5, 2007**

At its Board of Directors meeting January 20, 2007, United Fresh Produce Association first adopted a statement of principles and policy support for federal oversight of clear and strong produce safety standards based on the best available science.

At the Board's meeting on May 5, 2007, this policy position was reviewed and again endorsed, with the adoption of the following resolution supporting these guiding principles for a food safety regulatory framework for produce:

> *To protect public health and ensure consumer confidence, produce safety standards:*
>
> - *Must allow for a commodity-specific approach, based on the best available science.*
> - *Must be consistent and applicable to the identified commodity or commodity sector, no matter where grown or packaged in the United States, or imported into the country.*
> - *Must be federally mandated with sufficient federal oversight of compliance in order to be most credible to consumers.*

United Fresh
PRODUCE ASSOCIATION

# Prepared Statement


## Thomas E. Stenzel
## President and CEO
## United Fresh Produce Association


## Before the U.S. Senate
## Committee on Health, Education, Labor, and Pensions

## October 22, 2009

### Introduction

Good morning Chairman Harkin, Ranking Member Enzi, and Members of the Committee. My name is Tom Stenzel and I am President and CEO of the United Fresh Produce Association. Our organization represents more than 1,500 growers, packers, shippers, fresh-cut processors, distributors and marketers of fresh fruits and vegetables accounting for the vast majority of produce sold in the United States. We bring together companies across the produce supply chain from farm to retail, including all produce commodities, both raw agricultural products and fresh ready-to-eat fruits and vegetables, and from all regions of production.

I mention these characteristics because our organization's views on food safety are shaped by this broad and diverse membership across the entire produce industry, not any one sector or region. In the area of science and food safety, our association works to develop industrywide consensus on the best overall policies and practices to serve the American consumer.

Let me begin by repeating something you've heard many times before, and will hear many times in the future. Food safety is our industry's top priority. The men and women who grow, pack, prepare and deliver fresh produce are committed to providing consumers with safe and wholesome foods.

That is what drives food safety to be a process of continuous improvement, not a static achievement. We are on a continuum constantly striving to improve, while understanding scientifically that perfection – or zero risk – is not possible. Because our products are enjoyed by consumers in their fresh and natural state without cooking, we have to be right every single time – not one in a million, or even one in a billion.

Now, I personally am confident in my produce choices today. I know the personal care and commitment of people I meet who are growing and processing fresh produce, and I trust them to be doing their very best to market safe products. And I know that their results are overwhelmingly successful, with the actual incidence of illness extremely low. Just look at the numbers.

- Over a billion servings of fresh produce are eaten every day.
- More than 5 million bags of fresh salads are sold every day.
- And, out of the hundreds of fruits and vegetables offered in a typical supermarket, only a very few have been implicated in illness outbreaks, and then rarely as compared with their volume of consumption.

But, we also know that consumers today are walking into grocery stores and restaurants with concerns, doubts, and sometimes fears about produce. They don't understand those statistics; they don't know what farmers and processors are doing to protect the safety of their produce; and equally important, they do not have complete confidence that government is doing all it should to protect their health.

Most importantly, we cannot lose sight that health experts are unanimous that Americans must increase our consumption of fruits and vegetables for better health. That's the juxtaposition we face today on food safety – it is simply unacceptable for Americans to fear consuming fresh fruits and vegetables that are essential to their good health.

**Principles for Produce Safety**

Mr. Chairman, we have worked together to promote increased consumption of fresh fruits and vegetables for the health for America's children for many years, and you know that our industry's commitment to safety is the bedrock of that effort. Our commitment to produce safety is twofold.

First, we will do everything we possibly can as an industry to ensure the safety of the products we grow, package and deliver to consumers. Our association published the first *Food Safety Guidelines for the Fresh-Cut Produce Industry* 17 years ago, and we are now on our 4th edition. We developed the first industry guidelines in the mid 1990s to minimize on-farm microbiological food safety risks for fruits and vegetables, and worked closely with the FDA to publish federal guidelines soon thereafter. Food safety has been at the forefront of our mission to serve the American public for many years.

Following the E coli outbreak associated with one brand of spinach in September 2006, we undertook a comprehensive reevaluation of leafy greens production, handling and processing to enhance every possible step we could take in assuring safety. Even though that problem was isolated to one small farm, the entire leafy greens industry has adopted the most rigorous scientific principles to minimize risk, and developed compliance protocols and audits that are now conducted by state government officials.

Other commodity groups have done likewise, with the tomato industry implementing rigorous standards and metrics that even been incorporated in state law in Florida.

Earlier this year, our association brought together worldwide leaders in produce safety standards and auditing, launching an ongoing initiative to drive harmonization around the most rigorous set of good agricultural practices known as GAPs, applicable to all produce operations.

And, the committee should be familiar with our Produce Traceability Initiative (PTI), an industrywide commitment launched by three major trade associations in 2008 to drive a standardized, total supply chain traceability system with case coding to allow rapid traceback and isolation of any potential problems.

I can tell you with certainty today, that produce is safer today than ever before, with an unprecedented commitment from food safety from field to table.

Yet, we too know that there must be changes in our federal system of food safety oversight to restore public confidence in what too often appears to be a broken system. We have seen the failures of food safety oversight up close, first in failing to provide the resources and focus on prevention of contamination where most likely to occur, and second in misguided management of outbreak investigations that confuse the public about true risk and cast entire industry sectors into doubt.

In order to address these issues, our Board of Directors took the bold step three years ago to adopt a series of policy principles calling for mandatory, science-based regulation by the federal government. Let me repeat those principles once more:

> *To protect public health and ensure consumer confidence, produce safety standards:*
>
> - *Must allow for a commodity-specific approach, based on the best available science.*
> - *Must be consistent and applicable to the identified commodity or commodity sector, no matter where grown or packaged in the United States, or imported into the country.*
> - *Must be federally mandated with sufficient federal oversight of compliance in order to be most credible to consumers.*

Since that time, our industry has been a leading proponent of strong federal government oversight of food safety, testifying before the House or Senate more than 10 times, working extensively with FDA and USDA, and sharing perspectives with other stakeholders and the consumer community.

We are pleased that the consensus in Congress has grown in support of these principles, which have largely been incorporated into H.R. 2749 the Food Safety Enhancement Act passed by the House, and S. 510 the Food Safety Modernization Act of 2009 introduced by Senators Durbin and Burr and colleagues.

As this committee and the Senate consider changes to our food safety laws, let me explain the importance of each of these principles.

- <u>Must allow for a commodity-specific approach, based on the best available science.</u> We believe produce safety standards must allow for commodity-specific food safety practices based on the best available science. In a highly diverse industry that is more aptly described as hundreds of different commodity industries, one size clearly does not fit all. For example, the food safety requirements of products grown close to the ground in contact with soil are far different from those grown on vines or trees. And, the large majority of produce commodities have never been linked to a foodborne disease. In fact, a recent FDA federal register notice confirms that five produce commodities have been associated with 80% of all foodborne disease outbreaks in the past 10 years, and that is where we must direct our resources.

  In addition, government and industry alike must be careful that broad strokes do not result in requirements that should not apply to specific commodities, and do nothing to enhance safety. Taking a general approach would be far too easy to add regulatory costs and burdens to sectors where those requirements are unneeded, without doing anything to enhance safety where most critical. Finally, as part of this commodity specific approach, FDA must develop a rule-making procedure that establishes risk and science-based regulations for the production, handling and distribution of those types of

fruits and vegetables for which the Secretary determines such standards are necessary to minimize the risk of microbial illness.

- Must be consistent and applicable to the identified commodity or commodity sector, no matter where grown or packaged in the United States, or imported into the country. We believe produce safety standards must be consistent for an individual produce commodity grown anywhere in the United States, or imported into this country. Consumers must have the confidence that safety standards are met no matter where the commodity is grown or processed. Because of the variation in our industry's growing and harvesting practices in different climates and regions, flexibility is very appropriate and necessary. For example, some production areas use deep wells for irrigation while others use river water supplied from dams. Some farms use sprinkler irrigation, others use a drip system laid along the ground, and still others use water in the furrows between rows of produce. But the common factor must be that all uses of water for irrigation must meet safety standards that protect the product. That must be true whether the produce is grown in California, Florida, Wisconsin or Mexico.

- Must be federally mandated with sufficient federal oversight of compliance in order to be most credible to consumers. We believe achieving consistent produce safety standards across the industry requires strong federal government oversight and responsibility in order to be most credible to consumers and equitable to producers. We believe that the U.S. Food and Drug Administration, which is the public health agency charged by law with ensuring the safety of the nation's produce supply, must determine appropriate nationwide safety standards in an open and transparent process, with full input from the states, industry, academia, consumers and all stakeholders. We are strong advocates for food safety standards based on sound science and a clear consensus of expert stakeholders.

  In turn, it is important for FDA to work with its partners at the USDA and state departments of agriculture to ensure compliance with produce safety standards. We do not see a need for thousands of new FDA inspectors moved from processing plants to farms and fields, but rather a close working relationship with the USDA that understand agricultural production and can better monitor and assure compliance with FDA rules.

Together, these three policy principles provide a direction for food safety regulatory policy that we believe would most help our industry enhance produce safety, concurrent with establishing the highest level of public trust in our industry and in our fresh produce offerings. It is our goal to support a U.S. regulatory framework for the fresh produce industry that incorporates these principles.

**Outbreak Investigations**

While most of my testimony today is rightly focused on what we can do to prevent illness associated with our products, I must also include comments about the current management of outbreak investigations by federal, state and local government.

In testimony I presented last summer to the House Energy and Commerce Committee, I discussed the multitude of failures evident in the *Salmonella* Saintpaul outbreak in 2008 that was eventually linked to jalapeño peppers, but only after shutting down the tomato industry. In that testimony, I highlighted several fundamental flaws in outbreak management that I believe should also be addressed in reform of food safety laws.

**1. Diffuse Responsibility Creates Lack of Accountability**

The diffuse responsibility for public health in outbreak investigations results in no one agency or individual in charge, leaving local, state, and federal officials vying for leadership; various agencies pursuing different priorities; and well-meaning individuals reacting independently to events rather than as part of a coordinated investigation moving forward in a logical and expeditious direction. Another indicator of this problem is the lack of a coordinated national training program for investigators at the federal, state and local level. The resulting inconsistency of field work in these investigations is a major impediment to accurate and timely results.

We suggest Congress direct the Administration to put in place an outbreak investigation structure with a clear chain of command. Take guesswork out of who's in charge, and drive real authority and accountability into the process. We suggest examining the system for National Transportation and Safety Board investigations, which from afar, seems designed for a 24-7 immediate response, with clear authority and command leadership, supported by a team of well-prepared experts. Simultaneously, HHS should mandate and provide the resources for nationally consistent training for all local, state and federal employees involved in food safety investigations and inspections.

**2. The Current System Doesn't Use Industry Expertise**

The government's failure to use industry's expertise in outbreak investigations is one of our most important lessons. Let me first say that this needs to be a transparent process in order to have public credibility. But there is an abundance of knowledge in the industry about specific commodities, growing regions and handling practices, and specific distribution systems that can be used to protect public health in an outbreak. Based on geographic distribution patterns of illnesses alone, industry representative advised FDA quickly that tomatoes were extremely unlikely to be the source of contamination, yet such input was ignored until proved correct six weeks later when jalapenos chopped up in salsa were linked to the outbreak.

Congress and the agencies should find a proper and transparent way to bring industry expertise into its investigations. We specifically recommend that a group of experts in major produce commodities be selected and vetted by government well ahead of time, perhaps through a process similar to gaining a security clearance. Then, at a moment's notice, these pre-cleared experts could be assembled with government investigators to provide counsel in their areas of expertise.

**3. Today's Risk Communication Is Unacceptably Broad**

These are complex issues indeed, and tough to explain. The principle of timely and candid communication with the press and public cannot be compromised. Yet, the public is not well-served by stoking fear of all spinach, or all tomatoes, or any other commodity when the actual risk is very limited. Consider this fact – the 2006 E coli outbreak linked to spinach is now known to have been limited to one farm, one processing plant, on only one day's production run. There have been no further illnesses since that time reportedly linked to spinach. Yet, consumption of this nutritionally packed vegetable is still down from where it was three years ago. Public health is not well served by such misplaced fears.

**Congressional Food Safety Legislation**

Let me now discuss our thoughts on S. 510 the Food Safety Modernization Act now before the Senate. We support this bill as an aggressive and comprehensive approach to reforming food safety law. While we would like to see further direction to HHS for improving outbreak investigations, we believe many of the tough issues have been addressed in this legislation, leading to the bipartisan nature of it co-sponsors.

Specifically, we applaud the bill's commodity-specific approach to produce, which necessarily focuses resources where most needed. We applaud the bill's requirement that FDA work with USDA and the states in implementation and compliance measures. And, we applaud the bill's mandate for an expedited entry program for imports that can demonstrate compliance with U.S. food safety standards.

I also want to urge the committee to reject calls to "water down" the food safety requirements in the bill as a way to satisfy some who say that small farms, organic farms, or others should not have to comply. Mr. Chairman, I have a number of small farms and organic farms in our membership, and all are committed to following whatever food safety rules that FDA deems to be important to protect public health. Size does not determine whether food safety is important – every consumer's health is just as important whether purchasing vegetables at a farmers market or a grocery store. Our industry has learned the painful lesson that we are only as strong as our weakest link. If Congress truly wants to build public confidence in our food safety system, all fruits and vegetables must comply with basic safety rules no matter where or how grown.

Rather than seek exemptions from basic food safety requirements, we believe technical assistance, training and financial support – including reduced fees for all small businesses – are more appropriate ways to assist small resource farmers and produce distributors to comply with important food safety and traceability standards. We are confident that every produce grower – in this country or abroad – should be able to comply with the commodity-specific standards and guidance anticipated from FDA for the safe production and handling of fruits and vegetables.

We urge the committee to move swiftly in deliberations on S. 510 in order to allow Senate consideration this year. With H.R. 2749 pending, passage of S. 510 would provide strong Senate leadership in conference to formulate final bipartisan legislation that can be broadly supported by both chambers, industry and consumers.

**Conclusion**

In conclusion, let me return to the important role fresh fruits and vegetables play in public health. Of course any reasonable person in the food industry would want to produce only the safest possible product. But for us, somehow it seems even more important because of the healthfulness of fresh produce. The very Department of Health and Human Services that regulates our safety has the dual responsibility to promote the importance of eating more fruits and vegetables to prevent chronic diseases such as cancer, heart disease, stroke, and more. And now, our nation is faced with an obesity crisis that threatens the long-term health of our children and out-of-control escalation in health care costs unless we radically change eating habits to consume more fruits and vegetables.

With that public health imperative, fears of food safety have no place in the fresh produce department. We, as an industry, must do all we can to prevent illnesses from ever occurring, and we will.

But because science tells us there is no such thing as zero risk, government must also be able to assure the public that even if something does go horribly wrong in an isolated case, consumers can continue to have confidence in fresh produce. We must all be able to trust the overall system of government oversight and industry responsibility, working together to produce the safest possible supply of fresh, healthy and nutritious fruits and vegetables.

PRODUCE SAFETY PROJECT ISSUE BRIEF:

PRODUCE SAFETY PROJECT

# STANDARDS FOR IRRIGATION AND FOLIAR CONTACT WATER

Trevor V. Suslow, Ph.D.

## Introduction

Fresh and fresh-cut produce, including tree nuts and dried fruits, and specialty-niche crops (i.e. ethnic crops, culinary herbs, international horticultural foods) often are irrigated with ground water, surface water, and reclaimed or recycled water throughout the U.S. (USDA NASS, 2008 and 2009). As reviewed by Carr et al. (2004), it is estimated that 18% of worldwide cropland is irrigated, producing 40% of all food. A significant portion of irrigation water is wastewater. For example, estimates project at least 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater. (Carr et al., 2004). Between 2003 and 2008 the total irrigated acreage for U.S. farms and ranches increased almost 5% (NASS, 2009). Included in this trend were a 12% increase in ground water use and 22% increase in use of on-farm surface water sources. In the recent Census of Agriculture, NASS reports almost 10 million acres of commercial farm fruits, nuts, and vegetables in the U.S. and over 7 million of these under some form of irrigation management. California dominates the scale with almost 5.5 million acres of irrigated acres devoted to specialty crop production, which includes all stable, low moisture, and perishable horticultural food crops. Texas and Washington have substantial acres under irrigated specialty crop production and, proportionally, essentially all vegetable crop production in Arizona requires managed irrigation (See Table 1).

| | Distribution of Irrigation Methods {2008 NASS Survey} (2007 Response in 1000's acres) | | | |
|---|---|---|---|---|
| | Gravity (flood) | Sprinkler | Drip/Trickle | Sub-irrigation |
| United States | 22,018 | 30,877 | 3,756 | 200 |
| | | | | |
| Arizona | 764 | 178 | 54 | — |
| California | 4,190 | 1,367 | 2,336 | 66 |
| Florida | 473 | 185 | 549 | 56 |
| Texas | 1,032 | 4,192 | 173 | 500 |
| Washington | 200 | 1,379 | 138 | — |

Table 1. Overview of irrigation methods in key fruit and vegetable producing states.

**Trevor V. Suslow, Ph.D.**, Extension Research Specialist, Postharvest Quality and Safety, One Shields Ave, University of California, Davis, Department of Plant Sciences , Mann Lab Mail Stop 3, Davis, CA 95616-8780 ■ 530-754-8313 office ■ 530-752-4554 fax ■ http://ucgaps.ucdavis.edu, http://vric.ucdavis.edu , http://postharvest.ucdavis.edu

As greater attention over the past 20 years has been directed to the rising evidence and role for fresh produce in illness and outbreaks, pressure for increasingly specific and prescriptive food safety programs and associated standards has come from several directions. Though long debated internally and externally, the events surrounding outbreaks between 2005 and 2007, exemplified by the *E. coli* O157:H7 outbreak on spinach and processed lettuce in 2006, accelerated the efforts of produce industry leadership to define practical, meaningful, and measureable prevention practices and standardized audit criteria. These are often referred to as the 'metrics' associated with Good Agricultural Practices (GAPs) and Commodity–Specific Guidance documents (CSFSGLLGSC 2006; CSFSGLLGSC 2008; CSG T-GAPs 2006;CFFS-GFTSC 2008; CSG Tomato 2009). Several factors converged to convince many within the lettuce and leafy greens industry to forge and implement such standards, which would be the preliminary benchmarks for monitoring and compliance assessments. The prevailing approach was to adopt science-based standards anchored to a recognized authority or established metric for risk reduction wherever possible. One of the most contentious of these emerging metrics was the debate over irrigation water standards.

Eventually, the lettuce and leafy green industry sector developed a supply-side self-mandate that defined the parameters for irrigation water sampling and set uniform decision and action-points derived from these quality standards. These microbial limits were based on the United States Environmental Protection Agency's (EPA) recreational water quality criteria for full body contact (US EPA 1973). Though not universally embraced, eventually microbial limits, compliance criteria, and a decision-tree for corrective actions were adopted (CSFSGLLGSC 2006). Though surrounded by uncertainty as to the validity or applicability of the approach, these metrics were acceptable to their customers (fresh processors or foodservice and retail buyers). The hope was that having a system in place also would help restore confidence among consumers. Several foodservice and retail-led groups adopted the same or parallel standards for irrigation water. Though already in motion or adopted by other commodities, the large and economically devastating produce outbreak associated with *Salmonella enterica* sv. Saintpaul in 2008 had a pronounced impact on the fresh tomato industry to expedite uniform state regulated (CSG T-GAPs 2006), grower/handler association (CFFSGFTSC 2008), and national standards (CSG Tomato 2009), including irrigation water.

The focus and objective of this Issue Brief is to review the challenges and approaches to establishing functional and meaningful standards and microbiological limits for irrigation water used in the preharvest phases of fresh-consumed horticultural foods. Limited reference to foliar contact will be included relative to current practices regarding water quality and timing of applications. Where citation to scientific journal publications, other forms of peer-reviewed works, or publically available databases is not available, the author feels reference to reports of unpublished data or industry practice is justified to allow broader appreciation of the issues.

## Overview of the Issue

For most individuals, the term irrigation water is fairly self-evident. Foliar contact water in the context of preharvest (crop production) management applies to many less familiar practices including;

- **Pesticides** – typically insecticides, fungicides, and bactericides including microbial pesticides (biological control agents); may include herbicides at tolerant crop stages, though rarely.
- **Nutrients** – various macro and micro-plant nutrients (fertilizers) applied to aerial portions of plants for absorption rather than to the soil.
- **Growth regulators** - plant growth regulators (hormone-like substances) applied at various stages of plant development and for diverse purposes, generally to improve quality and marketability.
- **Manure teas and compost teas** – various infusions with pesticidal, nutrient, and growth regulator benefits reported.
- **Thinning aids** – plant growth regulators (hormone-like substances) applied at early stages of fruit set and development to reduce the crop load and increase individual fruit size and quality.
- **Harvest aids** – a wide range of low volume applications of potable water or water plus acidulants, chelating agents, or other compounds, typically at harvest, but included here in foliar contact
- **Frost control** – one strategy to protect certain sensitive crops from frost or freeze injury is to insulate the plant, and often fruit, with ice by applying continual foliar wetting with sprinklers or micro-misters
- **Anti-transpirants** – water soluble chemicals applied to foliage to reduce water loss
- **Dust control** – large volumes of water applied to unpaved farm access roads and harvest buffers to reduce dust, primarily from equipment and other farm traffic.
- **Microenvironment management** – water applied by various modes, though often micro-sprinklers or micro-misters to create evaporative cooling for quality management

The microbiological quality of water at the source and during storage, conveyance, and distribution on-farm can be highly dynamic. The flux in levels and diversity of pathogens is affected by many, often complex, interacting factors including climatic events, seasonal weather patterns, adjacent land uses, wildlife activities or migration, hydrogeologic characteristics of aquifers, agricultural activities, recreational activities and easements within agricultural settings and other forms of urban encroachment or urbanization, to name just a few.

## Irrigation water is a potential source for produce contamination

Irrigation water and any foliar applied water, with intimate contact to the developing or mature edible portions of fresh produce, has long been recognized as one of the most plausible and probable sources of fresh produce contamination with pathogens of concern for human health (Geldrich and Bordner, 1971; Hillborn et al., 1999; Ruiz et al., 1987; Sadovski et al., 1978; Wheeler et al. 2005).

The detection of pathogens in watershed run-off, recreational water, and irrigation source water, both domestically and globally, such as *Salmonella, E. coli* O157:H7 and other shiga-toxin producing *E. coli* (STEC), *Shigella*, hepatitis virus A, norovirus, *Cryptosporidium, Campylobacter,* *Listeria*, and others is well documented in recent overviews and reviews (Aruscavage et al., 2006; Avery et al., 2008; Doyle and Erickson, 2007; Ferguson et al., 2003; Gerba, 2009; James, 2006; Winfield and Groisman, 2003). The potential for persistence of these pathogens for various durations in research studies, once brought into contact with phyllosphere and rhizosphere surfaces of horticultural crops by artificially contaminated irrigation water, has been frequently reviewed and cited as a major risk factor and concern (Brandl, 2006; Fan et al., 2009; Hanning et al. 2009; Sapers et al., 2006; Teplitski et al., 2009). Recent field studies and investigations of contamination that resulted from the use of partially treated sewage effluent for vegetable irrigation (Ibenyassine et al., 2007; Rai and Tripathi, 2007) have added to the body of literature, primarily from the 1970's.

## Risks Associated with Irrigation Water

According to the most recent available NASS census (USDA NASS 2008 and 2009), over half of the total irrigated acreage in the United States (52.5 million acres) was applied by overhead irrigation. Among overhead-irrigated acreage, about 113,000 acres were berries, 81,000 acres were tomatoes, 162,000 acres were lettuce and romaine, and 1,110,000 acres were other vegetables. It was not possible to discriminate whether the source of irrigation water was surface or ground water for these crops, but regular use of surface water delivered through overhead irrigation equipment has been reported in a number of surveys of fresh fruit and vegetable producers.

Potential direct and indirect contamination of fresh produce with pathogenic microorganisms can result from contact with irrigation water, feces, soil, inadequately composted manure, dust, wild and domestic animals, and human handling (FDA 1998 and 2007). Irrigation water sources include wells, ponds, rivers, streams, municipal water sources, and reclaimed (treated wastewater) water. The complexity of on-farm irrigation water management is easily be appreciated by even a cursory list of the many ways irrigation water can be applied including overhead, furrow, flood, seep ditches, surface drip, and subsurface drip to name a few (Steele and Odemeru, 2004; Suslow 2002 and 2003.) Likelihood of contamination is also dependent on the commodity being grown. Stine et al. (2005a and 2005b) in conducting a quantitative microbial risk assessment noted that the irrigation method and type of produce grown influenced the transfer of microorganisms to produce through irrigation water. In related studies, Choi et al. (2004) and Song et al. (2006) utilized only subsurface drip and furrow irrigation and still found organisms could be transferred to the commodities through irrigation water. In the United Kingdom, a survey of salad (leafy greens) producers showed that the primary irrigation source was surface water delivered through overhead application with very limited monitoring of water quality. This study also found that the gap between the last application and harvest may be <24 hours in many cases. One concern this study discusses is the fact that rivers used for irrigation also serve as deposition sites for the majority of the United Kingdom's treated urban wastewater (Tyrell et al., 2006).

Irrigation water, which can be a source of pathogenic microorganisms, can ultimately contaminate agricultural products (Beuchat and Ryu, 1997; Gallegos-Robles et al. 2008; Guo et al., 2002; Solomon et al., 2002a and 2002b; Thurston-Enriquez et al., 2002). A variety of fecal contaminants and pathogens such as *E. coli*, *Salmonella spp.*, *Listeria* spp., *Crytosporidium*, and enteric viruses have been isolated from irrigation water and associated sediments (Borchardt et al., 2009; Jiang and Wu, 2004; Jiang et al., 2007; Loge et al., 2002; Lu et al. 2004; Morace et al., 2002).

In their investigation following the 2006 *E. coli* outbreak in spinach, the California Department of Health Services (CDHS) and U.S. Food and Drug Administration (FDA) identified contaminated irrigation water as a possible source of *E. coli* O157:H7 (CDHS FDA, 2007). Detailed analysis of the regional hydrogeological characteristics and specific weather conditions contemporary with the production of the implicated spinach suggested sub-surface transfer (discussed briefly later) as the cause of irrigation water contamination (Gelting, 2007). The spinach-related outbreak of *E. coli* O157:H7 in 2006 generated uncertainty among consumers and led to reduced consumption of packaged spinach (to 43% of prior consumption). Sales of packaged salads remains impacted, around 20% below prior periods (Calvin, 2007). This pivotal outbreak, for which economic consequences were estimated to be over $200 million (Calvin, 2007), is thought to have been caused by a single contamination event in a single spinach field (CDHS FDA, 2007). Though the outbreak was not conclusively linked to contaminated irrigation water, it contributed directly to demand for safety standards in the production of fresh produce. More recently, the CDC and FDA also identified irrigation water from a Serrano pepper farm in Mexico as a possible source of the 2008 *Salmonella enterica* sv. Saintpaul outbreak in the U.S (CDC, 2008). Lack of public confidence has clear economic impacts and undermines programs by public health officials to promote consumption of fresh fruits and vegetables by Americans (www.mypyramid.gov).

## Sources of Water

While there is concern for the quality of water designated for preharvest use in the major production regions of the U.S., surface water is generally viewed as more susceptible to fecal contamination than is ground water. Irrigation with surface water is expected to pose greater risk to human health than irrigation with water from deep aquifers drawn from properly constructed and protected wells. However there are clear concerns based on well-water surveys and the prevalence of human illness associate with contaminated ground water, particularly enteric viruses (Gerba and Smith, 2005; Pillai and Pillai, 1998; Sinclair et al., 2009). The potential for ground water contamination from surface events, such as flooding or storm-related run-off from areas of concentrated manure accumulation, manure lagoons, or sewage treatment facilities, is well characterized (Oron et al., 2001; Gerba, 2009; Ibekwe et al., 2004 and 2006). Soil and hydrogeologic characteristics of a region, particularly macro-pores and macro-channels can contribute to significant risks of sub-surface flow from surface contamination sources to both surface and ground water. The role of such features in waterborne outbreaks may be obtained in Dorner et al. (2006). During the outbreak investigation in 2006, a detailed CDC report provided suggestive arguments to associate atypical water level differentials between surface and ground water as a source of contamination of one well near the implicated field (Gelting, 2007). Though highly controversial and speculative, this analysis was the catalyst for dialogue between produce industry, public health officials, and regulators to evaluate the means to address regional ground water quality and protection concerns.

In addition, in some regions or within individual operations, even very deep wells may have points of surface water entry due to discontinuity of the dense clay barrier or at casing perforations designed for water capture at much shallower depths than the aquifer below an impervious clay layer. This may be part of the well design to take advantage of seasonal water availability above the zone of aquifer re-charge. Although there are additional sources of ground water contamination, one worth mentioning here is aquifer contamination from inoperative or abandoned wells. Investigations of the cause of wells that chronically fail coliform testing criteria have been associated with surface run-off intrusion to abandoned and uncapped bore-holes that were not on a farm map and not included in seasonal testing programs.

In most cases, the microbiological quality of surface water used for irrigation is not known because it is not tested in any meaningful frequency. Over the past three years, in particular, this situation has substantially changed in many regions of fresh produce production in the U.S. extensively in California and Arizona and in many areas that are major sources of fresh produce imports to the U.S. However, the overwhelming majority of this database is privately and tightly held. It is worth noting that "public disclosure" of elements and aspects of this data set, representing tens of thousands of individual irrigation water samples enumerated for *E. coli*, has been made in industry association annual meetings and workshops. Therefore, anecdotally one may say that the preponderance of data indicates that irrigation water in western regions of the U.S., the major source of domestic lettuce and leafy greens and other cool season vegetables, has very low levels of the currently accepted microbiological water quality indicator not related to wastewater treatment standards.

From the disclosed data it is not possible to distinguish the proportion of samples represented by groundwater or various types of surface waters. The comparability of quantitative data is equally unknown, at this time, as variation in source of the samples, sampling technique and initial volumes, sample handling, sub-sampling, test methods, and specifics of test protocols for enumeration are recognized as a potentially problematic.

## Questions about the Suitability of Recreational Water Standards for irrigation water

A limited, and arguably outdated, set of indicators of fecal contamination has been used by the fresh produce industry to assess the suitability of water used in preharvest crop production up to the point of harvest. Many regional GAP and CSC systems have relatively recently adopted EPA recreational water quality criteria for establishing action thresholds, in the absence of actual risk-based data based on irrigation water (CSFSGLLGSC 2006 updated 2009). As internal and external pressure is exerted for national standards, a simple approach has been to adopt these EPA criteria. Without a baseline of data to assess the applicability of the approach, it is not possible to assess the significance of the chosen metrics in contributing measurably to public confidence and actual safety goals.

Recreational water standards, based on *E. coli* or *Enterococcus* population density in the water body, were developed according to science-based criteria (US EPA 1973 and 1996). The subset of hierarchical criteria addressing health risk, selected by the produce industry, was the most stringent within the EPA matrix for testing. These Most Probable Number (MPN) values were calculated from observed human health risk posed by full-body contact at swimming beaches that were impacted by human sewage. Although the contamination sources, water type, and route of infection are dramatically different between swimming at beaches and consumption of fresh fruits and vegetables, the recreational water criteria are easily accessible and are anchored to a recognized federal agency rather than a produce industry-sponsored study or self-generated data assessment. In the absence of deep scrutiny this starting point for establishing industry performance standards seemed palatable to the general public.

The irrigation water quality standards first adopted by the LGMA in California (CSFSGLLGSC 2006; updated 2009), based on these recreational water criteria, have been migrating to other states. A prior similar approach, in 2001, with modifications to the EPA values, was established in British Columbia, Canada. The rationale for adopting a more restrictive set of crop dependent standards for irrigation of produce consumed raw (without cooking or equivalent terminal kill step) was explained in great detail (Marr, 2001). To paraphrase the California standards, water used for overhead irrigation must have a 5-sample rolling geometric mean *E. coli* density lower than 126 MPN or CFU/100 ml and no sample should have an *E. coli* density greater than 235 MPN or CFU/100 ml. Similarly, water used for drip or furrow irrigation must have a 5-sample rolling geometric mean *E. coli* density lower than 126 MPN or CFU/100 ml and no sample should have an *E. coli* density greater than 576 MPN or CFU/100 ml.

The science behind the recreational water criteria was intended to maintain a risk of gastrointestinal illness lower than eight cases per 1,000 swimmers at freshwater beaches (US EPA 1973; Marr, 2001) based on exposure to point-source, untreated human wastewater discharge or spill; thus, the criteria may not be relevant to irrigation water. As designed, the criteria were further based on correlation with recent fecal contamination events and research on the kinetics of indicator die-off to ambient levels. The EPA criteria, as they were not intended to apply to risks associated with irrigation management of edible crops, do not take into account the kinetics of die-off during post-irrigation intervals and exposure to environmental stresses associated with crop production. Controlled environment and field studies conducted within Quantitative Microbial Risk Assessments (QMRA) for irrigation water:commodity suggest a variable interval between a foliar contamination event due to irrigation and relative risk of illness (Stine 2005a and 2005b). Common recommendations of two-weeks to allow for appropriate die-off remain to be thoroughly tested. Though not yet subjected to peer-review for publication, recent on-farm studies with attenuated *E. coli* O157:H7 in the Salinas region of California indicate a rapid death curve but extended survivor tail following a simulated single foliar contamination event on lettuce and spinach (Harris 2008 and 2009; Koike et al. 2008 and 2009).

Non-point sources of the indicator *E. coli* and the recognized potential for environmental growth and persistence cast a shadow of the validity of universally perpetuating this specific metric. Results of two recent studies (Harwood et al. 2005; Duris et al., 2009) provide further evidence to question the validity of current indicators of sanitary water quality as indicated by *E. coli* density and its correlation to detection of *E. coli* O157:H7, *Salmonella*, and enteric viruses. Thus, though *E. coli* density may indeed be indicative of public health risk from all gastrointestinal pathogens, it may not indicate presence of select key food borne pathogens. In fact, Winfield and Groisman (35) concluded that "different rates of survival of *Salmonella* and *E. coli* in nonhost environments suggest that *E. coli* may not be an appropriate indicator of *Salmonella* contamination."

For its part, recognizing the limitations of the current irrigation standards, the FDA's recently released Draft Commodity Specific Guidance documents for leafy greens, melons and tomatoes (FDA 2009) provides no specifics, critical limits, or metrics based on indicators or pathogen prevalence in a standardized sample volume of any size. Producers are held to self-determination of the broadly applicable position that water should be "of appropriate quality for its intended use, obtaining water from an appropriate source, or treating and testing water on a regular basis and as needed to ensure appropriate quality." It is an understandable position for a regulatory authority in the face of substantial scientific uncertainty.

Many other indicators of water quality including various human, ruminant, and avian bacteria, coliphages, environmental chemicals, sterols, detergents, caffeine, specific nucleic acids, and a host of other approaches are well established or currently under investigation. None are perfect and most are currently beyond the economic or practical availability of a routine test for the fresh produce industry. It seems a certainty that emerging research will provide innovative options for irrigation water testing in the near future.

## Test methods and the challenge of strict "metrics"

A full discussion of the various approved test methods for drinking, environmental, waste-treatment, and recreational water monitoring would be too expansive for this Issue Brief. A key concern generated by the need to comply with strict critical limits associated with current industry metrics is the specificity of the enumeration method as applied to the intended purpose and sample matrix. Having accepted generic *E. coli* as the standard for monitoring of irrigation water and numeric limits for compliance and non-compliance, it is natural to be concerned that the accuracy of the test has been validated. As mentioned above, the issue is not generally problematic as the majority of irrigation sources test well below the current standards. Basing actionable thresholds on a rolling geometric mean reduces the chance of a temporary increase in indicator levels triggering severe economic hardships. However, for individual growers or regionally among growers along a common irrigation source or system, hitting a single sample value above the strict threshold, for example 235 MPN/100 ml for overhead irrigation, is a critical event. Avoidance of hitting these meaningless breakpoints, relative to actual risk, invites temptation towards unethical practices. Simply put, validated test methods for *E. coli* estimations that require sample incubations of 35 or 37C may be perfectly reasonable and sufficiently specific for dairy, meat, poultry, and other foods or environmental testing but are too permissive for applications to irrigation water testing and other produce-related applications. Commercial tests vary in their specificity for enumerating *E. coli* and positive reactions are well recognized among related non-pathogenic bacteria commonly found in water sources, on plant surfaces, and in soil. Even at warmer temperatures, more selective for fecal coliforms (aka thermotolerant coliforms), such as 42.5 to 44C, non-*E. coli* bacteria may be present and elevate the test outcome above a threshold limit for termination of irrigation with a water source or product acceptance. Fortunately, there are validated commercial tests available that have been found to have a very high selectivity for *E. coli*. Standards to meet the required performance specificity for irrigation water should be adopted and embodied in CSG's for fresh produce.

## Current water quality standards poorly define the relation between indicators, pathogens, and risk of consuming produce

Though irrigation water previously has been studied extensively (Gerba, 2009), these studies were concerned primarily with chemical rather than microbiological water-quality parameters. As a result, the knowledge gap regarding sanitary quality of irrigation waters is nationwide. Data are particularly scarce in areas where the fresh produce is direct marketed because many of these producers are not under industry pressure to test their irrigation water. The current lack of uniform standards that have accepted and compelling predictive value, relative to cost, in relation to known pathogen risk is a key barrier to implementing testing programs among growers. Public attention to recent outbreaks of foodborne illness led the U.S. produce industry to search for an authoritative source of standards to preliminarily set the microbiological safety of irrigation water. The choice to adopt EPA recreational-water criteria at the time, and especially in retrospect, did not appear to be a sound, science-based selection for direct application to irrigation water; however, in the absence of a publicly available database from extensive testing it was deemed the best option.

The risk to consumers by contaminated irrigation water due to external and, possibly, internal contamination of leafy greens has been recently reviewed in some detail (Brandl, 2006; Sapers et al. 2006; Fan, 2009; Gerba, 2009). In the United States, federal standards for irrigation quality do not yet exist and international standards are considered too permissive (FDA, 1998).The World Health Organization standard of <1,000 CFU fecal coliform/100 mL water, which may be used on fresh produce without restrictions (WHO, 1989; Buchanan and Dennis. 2001) is based on empirical epidemiological evidence not recognized as acceptable to U.S. public helath agencies. Despite best efforts and understandable limitations, current irrigation water quality criteria are among the most universally relevant, but the least satisfactory standards have been adopted. Generic (commensal) *E. coli* have been used as the indicator organism (IO) of choice; however no clear and supportable standards have been available to establish microbial limits or criteria that define suitable versus unacceptable quality for the diverse sources and modes of application.

The adoption of meaningful and predictive standards or criteria, particularly for irrigation water quality, is significantly hampered by the apparent lack of correlation between indicator coliforms or generic *E. coli* levels and the detectable presence of pathogens such as EHEC. Micro and mesocosm studies (Sherer et al. 1992; Anderson et al. 2005) have demonstrated the severe limitations of popular IO's, including commensal *E. coli*, in predicting pathogen presence or correlating to proportional survival following fecal contamination. Many reports have demonstrated that *E. coli* can survive and multiply in irrigation water, wastewater, subtropical sediments, and mineral water. Persistence of IO in the absence of detectable levels of pathogens and secondary growth, strongly suggest that the use of current IO is compromised and renders decision-making or rule-making based on presence/absence or numerical thresholds borrowed from stringent recreational water quality standards an unnecessarily self-penalizing practice.

## Fresh produce growers need the ability to differentiate high-risk irrigation water from low-risk irrigation water

Effective guidelines for health protection should be practical and adaptable to fresh produce production. Commodity, crop management practices, climate and region, other agro-ecological factors, and other modifiers should be evaluated in setting microbiological limits. WHO (Carr 2004 and 2005) has recommended inclusion of the following elements: (1) Evidence-based health risk assessment; (2) Guidance for managing risk (including options in disinfection treatment); and (3) Strategies for guideline implementation (including progressive implementation).

Suggestions for federal standards for irrigation water quality have, often mistakenly, assumed that water quality requirements for the use of wastewater in unrestricted irrigation are the appropriate benchmark. Wastewater reclamation standards that apply to fresh produce uses are far stricter than surface water quality requirements for unrestricted irrigation (Carr, 2005). Surface water in many places would not meet the EPA standard for irrigation with treated wastewater of ≤2.2 total coliforms per 100 ml. Long-standing guidance for surface waters used for irrigation specify ≤1,000 fecal coliform per 100 ml (USEPA, 1973). This poorly defined class of indicators and allowable population levels are now held to be unacceptable for fresh produce production where intimate contact with the edible plant parts is likely or inevitable. Without going into details, the higher standard for wastewater treatment is, at the same time, critical for human sewage handling due to known contamination potential of high concentrations of pathogens and commonly non-applicable for most irrigation sources. The low levels of indicators required for applications of reclaimed water are predicated on their validity as satisfactory evidence for a functional disinfection process control. Once the total coliform numbers drop to the specified level, from several orders of magnitude greater initial counts, the correlative data predicts pathogen levels will have dropped to non-detectable or safe levels in the water. While aspects of wastewater risk assessment studies and uses remains controversial, the rationale for the more stringent standards based on the certainty of pathogen contamination of the source material is sound.

## Foliar Contact Water Quality

The general issues and potential involvement of foliar applied water in preharvest pesticide applications in product contamination, revealed during outbreak investigations, is well covered in Brandl (2006), Fan et al. (2009), Doyle and Erickson (2007), Suslow et al. (2003) and within several chapters of James (2006), Sapers et al. (2006), and Fan et al. (2009). Human pathogens such as *E. coli* O157:H7 and non-typhoidal *Salmonella* have been shown to survive and potentially grow in many agrichemicals applied to aerial plant parts including foliar and fruit sprays (Guan et al. 2001 and 2005). The concerns for the safe production and use of manure and compost teas may be derived from the Issue Brief: Composting Criteria for Animal Manures.

The expectation that foliar applications for crop management of fresh produce will use only potable sources is widely held and largely followed in the U.S. However, it would be irresponsible within this brief discussion not to at minimum acknowledge that convenience and human nature sometimes dictates that water is drawn from the closest source to the point of application. Refilling spray tanks with water pumped or, in the case of very small operations, scooped into back-pack sprayers from uncharacterized surface water sources does happen. A further risk introduced from this potentially hazardous practice is the growth of pathogens within the application equipment as water temperature rises, especially if excess material is held in the tank for hours or overnight or if spray tanks and lines are not cleaned out after use. Even surface water sources that are tested periodically may have unsuspected sources of contamination in sediments that are picked up by improper placement of PTO or pump-driven siphons.

## Factors that affect contamination potential between sampling intervals

Water sampling frequency and timing relative to irrigation events are key limitations in the application of any testing program linked to food safety management for fresh produce. Irrigation water is mistakenly assumed to be a highly controllable farm input. This is especially true for surface water sources and, realistically, of greater concern for naturally-moving sources (rivers, creeks) or delivered/conveyed water systems (irrigation district canals) whose dynamic quality is largely or entirely beyond the control of the grower. These unique and dynamic hazards of temporal pathogen contamination have been extensively researched (Maki and Hicks, 2002; Wang and Doyle, 1998;

Winfield and Groisman, 2003) and recently reviewed by Gerba (2009). The key unique risk factors relate to sediments as a reservoir for pathogen survival and their redistribution or de-stratification during turbulent flow or mechanical disturbances. For some water sources, wind-driven channeling waves or storm-driven disturbances can cause significant localized or broad-scale mixing at various water:sediment boundaries. Additional sources of sediment suspension include the physical features of natural bed contours under high flow rates, canal design, especially branch-points, and various weirs, diversions, on-farm irrigation flow-control gates, and return-flow systems. Mechanisms for re-introduction of sediments are a shared concern with on-farm reservoirs which also require in-season management but the distinction, for this section, is the degree of control and planning or notification of human-derived disturbances.

The potential for human-derived disturbances of natural water sources and irrigation district systems is primarily a consequence of periodic maintenance including dredging, construction, and removal of algae, aquatic weeds, bull-rushes, and bank vegetation. Sediment dredging can temporarily introduce pathogen-laden silt and clay particles into the flow-stream and be carried long-distances. Growers have identified inconsistencies in agency notification of such maintenance activities, especially of concern during in-season intervals, as compromising their Sanitary Survey assumptions for water source hazards in GAPs plans. The timing of sampling relative to any such disturbance and an irrigation event strongly affects the opportunity to identify a potential risk in the absence of such regionally coordinated notification. Growers may not have alternative water sources during these periods or may have irrigated a crop prior to receiving an on-farm test result suggesting a potential up-flow problem. Some types of local construction projects (i.e. bridge support stabilization) and regional in-season maintenance of irrigation canals (dredging and algal scraping) is unavoidable and has caused non-compliant water test outcomes.

Algal control and disturbances of macro-algae flocs is an interesting and emerging topic for hazard analysis but beyond the scope of this Issue Brief. In brief, algal mats in irrigation water source reservoirs and distribution systems have long been recognized as undesirable from a practical management perspective. Byappanahalli et al. (2003 and 2009) reported that leachates from the common macro-algae *Cladophora* support the rapid *in vitro* growth of *E. coli.* Survival of *E. coli.* on collected dried thalli exceed six months at 4oC. Re-growth of *E. coli* following rehydration of dormant thalli reached levels exceeding log 8.0 CFU g -1. More recently, Ishii et al. (2006), from the same group, provided details of this potential reservoir for contamination and growth in natural lake waters. Macro-algae in recreational water bodies have been documented to seasonally harbor fecal indicator bacteria, *Salmonella, Shigella, Campylobacter*, and shiga-toxin producing *E. coli* (STEC) on free-floating flocs and mats attached to shoreline rocks, including environmentally-dried algal mats below the high water mark. Algal flocs and mats are speculated to serve as transient or seasonal habitat for these pathogens, providing nutrients and protection from lethal UV exposure and predation. In addition, over-wintering or contra-seasonal survival on dried mats may serve as a re-contamination reservoir and one source of re-introduction to water during in-season recharge. Recent preliminary surveys, conducted during 2008-09 seasons in California, have demonstrated the infrequent but positive recovery of STEC in association with algal flocs in irrigation canals (Suslow, unpublished data). These detection events have been largely restricted to late season sampling dates, consistent with periods of Harmful Algal Blooms (HAB) that clog waterways. Standard grab-sample (100ml) and larger volume assessments (5-10L) of the bulk water collected at the same time were negative for STEC in these studies. It will be important to determine whether algae are an environmentally significant contributor to IO populations in diverse irrigation source waters, independent of a detectable co-contribution to seasonal presence, survival, and periodic bloom-growth of pathogenic *E. coli* and *Salmonella* spp.

Mechanical removal and chemical controls have the potential to introduce pathogens into the bulk water used for irrigation at intervals between sampling dates or coincident with an irrigation event. Algal fragments may be picked up in water intake siphons and carried with the irrigation or foliar contact water, if taken from a surface source. Systems which employ pre-irrigation filters may largely remove particulates but our studies conducted to date have shown limited reduction in total bacterial removal by standard filtration alone. Whether environmental conditions and/or HAB development and mass-physiology trigger episodic release of fecal indicators and pathogens to water as planktonic cells or aggregates remains to be determined. The release of fecal indicators, the more common algal-associated enteric bacteria, could substantially and artificially impact water sample test results to levels above current standards which assume a recent fecal contamination event is indicated.

An interesting additional but uncertain factor that may influence irrigation water quality in some regions is the use of fish for aquatic weed control in government managed irrigation distribution networks. An example is the use of grass carp (*Ctenopharyngodon idellaby*) in the Imperial Irrigation District (IID) in southernmost California. Started as a research project in 1981, since 1985 the IID has been stocking sterile, triploid grass carp in their canal systems. Various naturally populated surface water sources have fish and many other forms of associated wildlife and domestic animals that may indirectly affect water quality. However, this example merely points out lack of specific information available to assess relative risks in relation to a category of source; river water vs. concrete-lined irrigation district canal.

## Future prospects: is a uniform standard attainable?

### *Direct detection of specific pathogens is both a way to validate and an alternative to, E. coli-based standards*

A single national standard for irrigation water quality applicable to all commodities, regions, and scales of production seems both unwise and unattainable without creating hardship to the fresh produce sector or allowing sporadic unacceptable levels of risk to consumers. Just as science-based criteria are required for recreational waters, science should be applied to formulate flexible and risk-based criteria for irrigation waters. One of the key on-going points of debate regarding these standards, including sampling frequency and location, is the sense of a large disparity between risk associated with ground water from deep aquifers and surface water. In some supplier qualification schemes, well water is held to a much higher standard than surface water, approaching drinking water microbiological criteria, because it is generally attainable. Growers with access to such high quality water from well protected wellheads have argued that frequent or continuous monitoring for *E. coli* levels merely generates a long series of zeros (<2.2 MPN/100ml). Counter arguments include the concern that sampling at the wellhead, while important, is insufficient and regular testing of the distribution system, especially if a sub-soil surface conveyance to on-farm risers and valves, at the point of application (i.e. gated pipe, sprinkler head) in some standardized pattern is warranted. However, this is more an issue of prevention and integrity of water quality protection practices rather than a source assessment. Regardless, these and other variations in BMP's for irrigation water quality sampling and testing remain to be resolved and harmonized.

Before expanding the current recommendation of *E. coli*-based standards for irrigation water to federal regulations, it will be important to assess whether any *E. coli*-based criterion would be relevant to indicate the presence of specific pathogens. The alternative may be to use direct detection of the target pathogens to indicate sufficient quality for waters used to irrigate fresh produce. A set of recommended practices for sample size and performance-tested methods may be derived from published studies, such as Castillo et al. (2004) and Loge et al. (2002). In the later study, the two principal factors influencing the direct detection limit for several key pathogens was sample volume, liters rather than 100ml, and the presence of inhibitory compounds in the purified nucleic acid extracts.

One solution for some growers faced with the uncertainty of irrigation standards, or the repeated failure of the only available water source to meet the metrics for indicator bacteria, has been to treat the water. Two of the more popular treatments, though still a very limited practice across the U.S., are injection of calcium hypochlorite or chlorine dioxide. The design of the dosing system is, in general, to bring the indicator *E. coli* levels within a compliant range and less commonly to meet drinking water criteria. For irrigation of many key crops, the volumes of water being pumped for overhead irrigation, for example, may be in excess of 1500 gallons per minute. In California and Arizona farms where this is being applied, water quality is generally good and the disinfectant demand is low. Therefore, low doses, 2-5 mg/L (2-5 ppm) of active ingredient are sufficient. This lessens the concern for detrimental effects on the farm soil or the environment from disinfection by-products (FAO/WHO 2009) in the short-term. Concerns remain for chronic effects of large-scale use over long periods of time on the degradation or soil quality and negative impacts on wildlife and habitats. Other water treatments with minimal concerns, such as ozonation and UV, are too costly for most producers but have been installed with low flow systems on high value crops including precision drip delivery for berry production.

Effective control of irrigation-water quality will depend on the economics of control. Producers cannot make informed decisions, given the current state of information regarding irrigation water, about choice of commodities to grow, at what time and from what source to irrigate, and whether to sacrifice yield for safety by choosing not to irrigate with high-risk water. Among current knowledge gaps are: (1) the sanitary quality of many irrigation water sources, (2) the relation between density of traditional fecal-indicator bacteria (such as *E. coli*) and the risk of encountering key foodborne pathogens (such as *E. coli* O157:H7 and *Salmonella*), (3) the remediation costs for contaminated water prior to irrigation, 4) the willingness of producers to adopt and enforce variable irrigation water quality standards.

## Acknowledgements

The Produce Safety Project would like to thank for their review of this paper:

PSP advisors Paul B. Allwood, Douglas L. Archer, and Barbara Kowalcyk; and Dr. Max Teplitski, Assistant Professor, University of Florida, Department of Soil and Water Science.

*The views in this paper do not necessarily reflect the views of the reviewers or The Pew Charitable Trusts.*

## Citations

Anderson, K. L., J. E. Whitlock, and V. J. Harwood. 2005. Persistence and Differenatial Survival of Fecal Indicator Bacteria in Subtropical Waters and Sediments, 71: 3041-3048.

Aruscavage, D. L., K. Miller, S. LeJeune, J.T. . 2006. Interactions Affecting the proliferation and control of human pathogens on Edible plants. . Journal of Food Science 71:89-99.

Avery, L. M., A. P. Williams, K. Killham, and D. L. Jones. 2008. Survival of Escherichia coli O157:H7 in waters from lakes, rivers, puddles and animal-drinking troughs. *The Science of the total environment* 389:378-385.

Borchardt MA, Spencer SK, Bertz PD, Ware MW, Dubey JP, Alan Lindquist HD. 2009. Concentrating Toxoplasma gondii and Cyclospora cayetanensis from surface water and drinking water by continuous separation channel centrifugation. Journal of applied microbiology.107:1089-97.

Brandl, M. T. 2006. Fitness of human enteric pathogens on plants and implications for food safety. Annual Rev. Phytopath. 44:367-392.

Buchanan, R.L. and S.B. Dennis. 2001. Microbial risk assessment: a tool for regulatory decision making. *J. Association of Food and Drug Officials*, 65 36-46.

Byappanahalli, M., Shively, D., Nevers, M., Sadowsky, M., and R. Whitman. 2003. Growth and survival of *Escherichia coli* and enterococci populations in the macro-alga *Cladophora* (Chlorophya). FEMS Microbiology Ecology. 46:203-211

Byappanahalli, M., Sawdey, R., Ishi, S., Shively, Ferguson, J., Whitman, R. and M., Sadowsky. 2009. Seasonal stability of Cladophora-associated Salmonella in Lake Michigan watersheds. Water Research 43:806-814

Calvin, L. 2007. "Outbreak Linked to Spinach Forces Reassessment of Food Safety Practices. 5:24-31. www.ers.usda.gov/AmberWaves/June07/Features/Spinach.htm

Carr, R.M., Blumenthal, U.J. and D. D. Mara. 2004. Guidelines for the safe use of wastewater in agriculture:

revisiting WHO guidelines. Water Science and Technology. 150:31-38.

Carr, R.M. 2005.WHO Guidelines for safe wastewater Use: More than just numbers. Irrigation and Drainage. 54:103–111

CAST (Council for Agricultural Science and Technology). (2006). Using Risk Analysis to Inform Microbial Food Safety Decisions. CAST Issue Paper 31. Ames, IA. June.

Castillo, A., Mercado, I., Lucia, L. M., Martínez-Ruiz, Y., Ponce de León, J., Murano, E. A., Acuff, G. R. 2004. *Salmonella* contamination during production of cantaloupe: a binational study. Journ. Food. Prot.71:2217-2222

CDC. 2008. Outbreak of *Salmonella* Serotype Saintpaul Infections Associated with Multiple Raw Produce Items — United States. MMWR. 57;929-934

CDHS FDA. 2007. California Department of Health Services and US Food and Drug Administration. Investigation of an *Escherichia coli* O157:H7 outbreak associated with Dole pre-packaged spinach. 2007;1–50. Available from http://www.dhs.ca.gov/ps/fdb/html/food/envinvrpt.htm

Choi C, Song I, Stine S, Pimentel J, Gerba C. 2004.Role of irrigation and wastewater reuse: comparison of subsurface irrigation and furrow irrigation. Water Sci Technol 50: 61-68.

Cook, R.L. 2001. The U.S. Fresh Produce Industry: An Industry in Transition. Chapter 2 in *Postharvest Technology of Horticultural Crops*, Adel A. Kader (eds.), University of California Division of Agriculture and Natural Resources, Publication 3311 (2001): 5-30.

CSFSGLLGSC. 2006 updated July 2009. Commodity Specific Food Safety Guidelines for the Lettuce and Leafy Greens Supply Chain 1st ed. Accessible at http://www2.wga.com/DocumentLibrary/scienceandtech/LGMAAcceptedGAPs07.10.09.pdf

CSFSGLLGSC.2008. Commodity Specific Food Safety Guidelines for the Lettuce and Leafy Greens Supply Chain. Version 2 –Arizona. http://www.azlgma.gov/userfiles/Leafy%20Greens%20Guidance%20Arizona%20Clean%20082608.pdf

CSFSGFTSC. 2008. *Tomato Guidance* Document, 2nd Edition, *Commodity Specific* Food Safety Guidelines for the Fresh. *Tomato* Supply Chain. Accessible at http://www.unitedfresh.org/assets/files/Tomato%20Guidelines%20July08%20FINAL.pdf

CSC T-CAPs. 2006. Tomato Good Agricultural Practices (T-GAP) and Tomato Best Management Practices (T-BMP). http://www.floridatomatoes.org/FoodSafety/TOMATO_QA_on_T-GAP_and_T-BMP11-8-06.pdf

CSC Tomato. 2009. Food Safety Programs and Auditing Protocol for the Fresh Tomato Supply Chain http://www.unitedfresh.org/assets/tomato_metrics/Open_Field_Checklist.pdf

Dorner, S.M., Anderson, W., Slawson, R., Kouwen, N. and Peter M. Huck. 2006. Hydrologic Modeling of Pathogen Fate and Transport. Environ. Sci. Technol.40: 4746–4753

Doyle, M. and M. Erickson. 2007.Summer meeting 2007—the problems with fresh produce: an overview. J Appl Microbiol 105:317–330.

Duris, J.W., Haack, S.K. and L. R. Fogarty, 2009. Gene and Antigen Markers of Shiga-toxin Producing *E. coli* from Michigan and Indiana River Water: Occurrence and Relation to Recreational Water Quality Criteria. J Environ Qual. 38:1878-1886

FAO/WHO. 2009. Benefits and risks of the use of chlorine-containing disinfectants in food production and food processing: report of a joint FAO/WHO expert meeting, Ann Arbor, MI, USA, 27–30 May 2008.

Fan, X. et al. 2009. Microbial Safety of Fresh Produce. Eds. Blackwell-Wiley and IFT Press.

FDA (1998). "Guidance for Industry: Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables." Federal Register, October 29, 1998 63(209): 58055-58056.

FDA. 2007. Food Protection Plan. [http://www.fda.gov/foodprotection/].

FDA. 2009. Proposed Commodity Specific Guidance Documents. Guide to Minimize Food Safety Hazards of Leafy Greens, Melons, and Tomatoes. http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/FruitsVegetablesJuices/FDAProduceSafetyActivities/ucm174086.htm

Ferguson, C., d. R. Husman, et al. (2003). "Fate and transport of surface water pathogens in watersheds." Crit. Rev. Environ. Sci. Ecol. 33: 299-361.

Gallegos-RoblesMA,Morales-LoredoA,Alvarez-OjedaG,VegaPA,Chew MY, Velarde S, and P. Fratamico. 2008. Identification of Salmonella serotypes isolated from cantaloupe and Chile pepper production systems in Mexico by PCR-restriction fragment length polymorphism. J Food Prot. 71:2217-2222.

Geldreich, E. E., and R. H. Bordner. 1971. Fecal contamination of fruits and vegetables during cultivation and processing for market - a review. *J Milk Food Technol* 34:184-195.

Gelting, R. 2007. Irrigation water issues potentially related to 2006 *E. coli* O157:H7 in spinach outbreak. CDC Addendum Report. Attachment 11: 24 pp.

Gerba, C. P. and J. E. J. Smith (2005). "Sources of pathogenic microorganisms and their fate during land application of wastes." J. Environ. Qual. 34: 42-48.

Gerba, C.P. 2009. The Role of Water and Water Testing in Produce Safety. Chapter 7 in Microbial Safety of Fresh Produce X. Fan et al. Eds. Blackwell-Wiley and IFT Press.

Guan, T. et al. 2001. Fate of foodborne bacterial pathogens in pesticide products. J. Sci. Food Agri. 81:503-512

Guan, T., Blank, G. and R.A. Holley. 2005. Survival of pathogenic bacteria in pesticide solutions and on treated tomato plants. Journal of Food Protection. 68:296-304.

Guo, X., van Iersel, M., Chen, J., Brackett, R., and Beuchat, L. 2002. Evidence of association of *Salmonellae* with tomato plants grown hydroponically in inoculated nutrient solution. Applied and Environmental Microbiology 68:3639-3643.

Hanning, I., Nutt, J.D. and S.C. Ricke. 2009. Salmonellosis outbreaks in the United States due to fresh

produce: Sources and potential intervention measures. Foodborne Pathogens and Disease. 69:635-648.

Harrington, J. 2009. Water for Agriculture: Global Change and Geographic Perspectives on Research Challenges for the Future. *Journal of Contemporary Water Research & Education* 142:36-41

Harris, L.J. 2008.Survival of attenuated *Escherichia coli* O157:H7 or surrogate in field-inoculated lettuce. California Lettuce Research Board 2008 Research Report. http://www.calgreens.org/

Harris, L.J. 2009.Survival of attenuated *Escherichia coli* O157:H7 or surrogate in field-inoculated lettuce. California Lettuce Research Board 2009 Research Report. http://www.calgreens.org/

Harwood, V. et al. 2005. Validity of the Indicator Organism Paradigm for Pathogen Reduction in Reclaimed Water and Public Health Protection. Appl Environ Microbiol. 71: 3163–3170.

Hillborn, E.D., Mermin, J.H., Mshar, P.A., Hadler, J.L., Voetsch, A.,Wojtkunski, C. et al. 1999. A multistate outbreak of *Escherichia coli* O157:H7 infections associated with consumption of mesclun lettuce. Arch. Intern. Med. 159: 1758–1764.

Ibekwe, A.M., Watt, P., Shouse, P. and C. M. Grieve. 2004. Fate of *Escherichia coli* O157:H7 in irrigation water on soils and plants as validated by culture method and real-time PCR. Can. J. Microbiol. 50: 1007-1014.

Ibekwe, A.M., P., Shouse, P. and C. M. Grieve. 2006. Quantification of survival of *Escherichia coli* O157:H7 on plants affected by contaminated irrigation water. *Eng. Life Sci.* 6:566–572.

Ibenyassine K, Mhand RA, Karamoko Y, Anajjar B, Chouibani MM, and M. Ennaji. 2007.Bacterial pathogens recovered from vegetables irrigated by wastewater in Morocco. *J Environ Health*. 69:47-51.

Ishii, S., T. Yan, et al. (2006). "Cladophora (Chlorophyta) spp. harbor human bacterial pathogens in nearshore water of Lake Michigan." Appl Environ Microbiol 72: 4545-53.

Islam, M., J. Morgan, M. P. Doyle, S. C. Phatak, P. Millner, and X. Jiang. 2004. Persistence of Salmonella enterica serovar typhimurium on lettuce and parsley and in soils on which they were grown in fields treated with contaminated manure composts or irrigation water. Foodborne Pathog Dis 1:27-35.

James, J. L., ed. 2006. *Microbial Hazard Identification of Fresh Fruit and Vegetables*. John Wiley and Sons, Inc., Hoboken, NJ.

Jiang, S. C. and W. Chu. 2004. PCR detection of pathogenic viruses in southern California urban rivers. J. Appl. Microbiol. 97:17-28.

Jiang, S. C., W. Chu, B. H. Olson, J. He, S. Choi, J. Zhang, J. Y. Le, P. B. Gedalanga. 2007. Microbial source tracking in a small southern California urban watershed indicates wild animals and growth as the source of fecal bacteria. *Applied Microbiology and Biotechnology* 76 (4): 927-934

Koike, S. T., Cahn, M. D., and Suslow, T. V. 2008. Survival of generic *E. coli* under different irrigation systems. California Leafy Greens Research Board. 2007-2008 Annual Report. http://www.calgreens.org/

Koike, S. T., Cahn, M. D., and Suslow, T. V. 2009. Survival and biology of *E. coli* under field production environments. California Leafy Greens Research Board. 2008-2009 Annual Report. http://www.calgreens.org/

Loge, F., Thompson, D. and D. R. Call. 2002.PCR Detection of Specific Pathogens in Water: A Risk-Based Analysis. *Environ. Sci. Technol.*, 2002, 36:2754–2759

Lu, L., . Humea, M., Sternesc, K.L., and S. D. Pillaia, 2004. Genetic diversity of Escherichia coli isolates in irrigation water and associated sediments: implications for source tracking. Water Research. 38:3899–3908.

Maki, R. P., and R. E. Hicks. 2002. Salmonella typhimurium survival and viability is unaltered by suspended particles in freshwater. *J Environ Qual* 31:1702-1709.

Marr, B. 2001. Principles for Preparing Water Quality Objectives in British Columbia. Publication of the Ministry of Environment, Lands and Parks. Government of British Columbia, CN.

Morace,G. et al. . 2002. Microbial quality of wastewater: detection of hepatitis A virus by reverse transcriptase-polymerase chain reaction. Journal of Applied Microbiology. 92:828 - 836

Oron G, Armon R, Mandelbaum R, Manor Y, Campos C, Gillerman L, Salgot M, Gerba C, Klein I, Enriquez C. 2001. Secondary wastewater disposal for crop irrigation with minimal risks. Water Sci Technol 43: 139-146.

Pillai, S. D. and S.D. Pillai. 1998. Microbial Pathogens within Aquifers: Principles and Protocols. Springer Verlag. New York, NY. 163 pp.

Rai PK and Tripathi B.D. 2007. Microbial contamination in vegetables due to irrigation with partially treated municipal wastewater in a tropical city. *Int J Environ Health Res*. 17:389-395.

Ruiz, B. G. V., R. G. Vargas, and R. Garcia-Villanova. 1987. Contamination of fresh vegetables during cultivation and marketing. *Int J Food Microbiol* 4:285-291

Sadovski AY, Fattal B, Goldberg D, Katzenelson E, Shuval HI. 1978. High levels of microbial contamination of vegetables irrigated with wastewater by the drip method. Appl Environ Microbiol 36: 824-830.

Sapers, G. M., J. R. Gorny, and A. E. Yousef, eds. 2006. *Microbiology of Fruits and Vegetables*. CRC Taylor & Francis Group, Boca Raton.69.

Sherer, B., Miner, J., Moore, J., and J. Buckhouse. 1992. Indicator bacterial survival in stream sediments. Journal of Environmental Quality 21:591-595.

Sinclair RG, Romero-Gomez P, Choi CY, Gerba CP. 2009. Examination Of MS-2 Phage And Salt Tracers To Characterize Axial Dispersion In Water Distribution Systems. J Environ Sci Health. 10:963-971

Sivapalasingam, S., Barrett, E., Kimura, A., Van Duyne, S., Phan, W. W. Q., Gould,E, Shillam, P., Reddy, V., Cooper, T., Hoekstra, M., Higgins, C., Sanders, J., Tauxe, R., and Slutsker, L. 2003. A multistate outbreak of *Salmonella enterica* serotype Newport linked to mango consumption: Impact of water-dip disinfestation technology. Clinical Infectious Diseases 37:1585-1590.

Solomon, E.B., Yaron, S., and Matthews, K.R. 2002*a*. Transmission of *Escherichia coli* O157:H7 from contaminated manure and irrigation water to lettuce plant tissue and its subsequent internalization. Appl. Environ. Microbiol. 68: 397–400.

Solomon, E.B., Potenski, C.J., and Matthews, K.R. 2002*b*. Effects of irrigation methods on transmission to and persistence of *Escherichia coli* O157:H7 on lettuce. J. Food Prot. 65: 673–676.

Song, I., S. W. Stine, et al. (2006). "Comparison of crop contamination by microorganisms during subsurface drip and furrow irrigation." J. Environ. Engin. 132: 1243-1248

Steele, M., and Odemeru, J. 2004. Irrigation water as a source of food-borne pathogens on fruits and vegetables. Journal of Food Protection 67:2839-2849.

Stine, S. W., I. Song, C. Y. Choi, and C. P. Gerba. 2005. Application of microbial risk assessment to the development of standards for enteric pathogens in water used to irrigate fresh produce. Journal of Food Protection 68:913-918.

Stine SW, Song I, Choi CY, Gerba CP. 2005b. Effect of relative humidity on preharvest survival of bacterial and viral pathogens on the surface of cantaloupe, lettuce, and bell peppers. J Food Protect 68: 1352-1358.

Suslow, T.V. 2002. Production practices affecting the potential for persistent contamination of plants by microbial foodborne pathogens. Chapter 16. In: Phyllosphere Microbiology. APS Press, Minneapolis, MN. pp. 241-256

Suslow, T.V., M.P. Oria, L.R. Beuchat, E.H. Garrett, M.E. Parish, L.J. Harris, J.N. Farber, F.F. Busta. 2003. Production practices as risk factors in microbial food safety of fresh and fresh-cut produce. Comprehensive Reviews in Food Science and Food Safety 2S:38-77.

Teplitski, M., Barak, J.D. and K. R Schneider. 2009.Human enteric pathogens in produce: un-answered ecological questions with direct implications for food safety. Current Opinion in Biotechnology. 20:166–171

Tyrell, S., Knox, J., and Weatherhead, E. 2006. Microbiological water quality requirements for salad irrigation in the United Kingdom. Journal of Food Protection 69:2029-2035

USDA NASS. 2009. 2007 Census of Agriculture. Specialty Crops Volume 2 Part 8. Accessible at www.nass.usda.gov

USDA NASS. 2008. Farm and Ranch Irrigation Survey. www.agcensus.usda.gov www.agcensus.usda.gov

USEPA (1973). *Water Quality Criteria*. National Academy of Sciences Report to the United States Environmental Protection Agency. USEPA, Washington DC, pp. 350–366.

USEPA. 1996. National water quality inventory, 1996 report to Congress. EPA 841-R 97-008. U.S. EPA, Washington, D.C.

Wang, G., and M. P. Doyle. 1998. Survival of enterohemorrhagic *Escherichia coli* O157:H7 in water. J. Food Prot. 61:662–667.

Wheeler, C., T. M. Vogt, G. L. Armstrong, G. Vaughan, A. Weltman, O. V. Nainan, V. Dato, G. Xia, K. Waller, J. Amon, T. M. Lee, A. Highbaugh-Battle, C. Hembree, S. Evenson, M. A. Ruta, I. T. Williams, A. E. Fiore, and B. P. Bell. 2005. An outbreak of hepatitis A associated with green onions. *N Engl J Med* 353:890-897.

WHO. 1989. Health Guidelines for the Use ofWastewater in Agriculture and Aquaculture. Report of a Scientific Group, Technical Report Series 778. World Health Organization: Geneva; 74 pp

Winfield, M. D., and E. A. Groisman. 2003. Role of Nonhost Environments in the Lifestyles of Salmonella and Escherichia coli, 69:3687-3694.

# HEALTH-RELATED COSTS FROM FOODBORNE ILLNESS IN THE UNITED STATES

PRODUCE SAFETY PROJECT

by Robert L. Scharff[1]
For the Produce Safety Project at Georgetown University[2]

March 3, 2010

Foodborne illness is a serious public-health problem in the United States. In 1999, the Centers for Disease Control and Prevention (CDC) estimated that approximately 76 million new cases of food-related illness (resulting in 5,000 deaths and 325,000 hospitalizations) occur in the United States each year [1]. More recent data on sporadic illnesses and outbreaks suggests that this problem is not going away [2, 3].

At the same time, the aggregate economic cost of health losses associated with foodborne illnesses has not been sufficiently examined. The few studies that provide cost estimates are incomplete and/or based on limiting assumptions [4]. For example, most cost estimates include only a few, if any, of the long-term health outcomes associated with acute foodborne illnesses [5]. The derivation of an accurate cost-of-illness measure for foodborne illness is important as a guide to policymakers who seek to allocate scarce resources to programs designed to improve the health of Americans. The Government Accountability Office (GAO) reports that, in 1999, the same year of the CDC estimate, the federal government spent $1 billion on food safety efforts, while state governments spent another $300 million [6]. Without a good measure of the scope of the problem these funds are targeted towards, it is impossible to determine whether such expenditures—which are even more substantial a decade later—are reasonable.

In this study, I use the Scharff et al. (2009) enhanced food-safety, cost-of-illness model to provide a more complete estimate of the aggregate health costs from foodborne illness in the United States [7]. This approach is an improvement over past studies because it takes into account illnesses from all pathogens identified by Mead et. al. (1999); includes measures for health losses that are not included in many past studies; and presents uncertainty using confidence intervals and a sensitivity analysis. The methodology follows principles used by economists at the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA), the two primary food-safety agencies in the United States.

The primary objective of this study is to provide policymakers with measures of the economic burden of foodborne illnesses, both at the aggregate level and at the pathogen-specific level. The derivation of a measure for the aggregate health costs of foodborne illness is useful as a means of evaluating the importance of this problem relative to other pressing health problems. I do not include every cost associated with foodborne illness. Instead, I focus on costs of acute foodborne illnesses and a few long- term health-related costs. Costs to industry from reputation externalities and recalls are significant, but are not covered here. Nevertheless, my best estimate for the cost of foodborne illness in the U.S. is $152 billion a year. This suggests that foodborne illness continues to be a significant problem in the United States. Below, I present estimates of the cost of foodborne illness, both at the aggregate and pathogen- specific levels. I also examine how this cost of illness is distributed across the states. More detail about the methodology used can be found in Appendix B.

1 Dr. Scharff is a former Food and Drug Administration (FDA) economist and is currently an assistant professor in the Department of Consumer Sciences at The Ohio State University.

2 I would like to thank the Produce Safety Project at Georgetown University, an initiative of The Pew Charitable Trusts, for the financial support they provided for this project. I would also like to thank Jodi Letkiewicz and Jiyeon Son for their superb research assistance; Frank Ackerman, Tanya Roberts, and Richard Williams for the helpful comments they gave as independent reviewers of this report; Jim O'Hara for his guidance and comments along the way; and Angela Lasher for her valuable input into earlier versions of the economic cost model

The health-related cost of foodborne illness in the United States is the sum of medical costs (hospital services, physician services, and drugs) and quality-of-life losses (deaths, pain, suffering, and functional disability). This cost includes both costs to the person made ill (e.g., pain and suffering losses) and costs to others in society (e.g. costs to insurance companies that pay medical expenses). Costs can be measured in a number of ways. Use of "willingness to pay" (WTP) to avoid illness, measurement of the monetary costs of illness to society, and hybrid approaches using both willingness-to-pay and monetary cost measures have all been used.

If the focus is on individual loss of well-being, a frequently-used economic measure is one that will accurately measure individuals' willingness to pay to avoid illness. Although these WTP studies do not elicit values not impacting the person whose value is measured, such as external medical costs covered by insurance, missing values can be added later if the analysis is focused on social costs. The most direct means of assessing WTP is through a stated-preference survey asking individuals to state the value of a small reduction of risk. These studies will only be accurate, however, if individuals answer survey questions in a fully informed and nonbiased manner. Using the stated-preference technique, Fox et al. (1995) estimated that the WTP to avoid a case of salmónellosis was between $68,000 and $191,800 [8]. More recently, Hammitt and Haninger (2007) found that the implicit WTP to avoid one mild case of foodborne illness (resulting in one day of illness that was not virulent enough to cause the person sickened to miss work) was $8,300 for adults and $24,900 for children [9]. The magnitude of these values, coupled with their lack of sensitivity to duration and severity, suggest that cognitive limitations in dealing with risk numbers might have led to an upward bias in elicited responses. Based on the Hammitt and Haninger survey and CDC data on the age distribution of illness severities, Roberts (2007) estimated that the annual cost of foodborne illness was $357 billion to $1.4 trillion [10].

Revealed preference (hedonic) studies are an alternative to stated-preference surveys. Using this method, economists look at actual behavior in the marketplace and infer a value for a given attribute (i.e. food safety) from product price differentials with varying levels of the particular attribute. This type of study will only yield accurate estimates if consumers have an intuitively accurate estimate of the risks associated with alternative products. This is unlikely to be the case in the food safety context. Despite the lack of a holistic hedonic measure, revealed- preference studies can play a role in estimating the cost of foodborne illness. Widely-cited estimates of the value of a statistical life and value of statistical life year have been calculated using this method [11]. These values can be used to attribute costs to both deaths and quality-of-life losses.

The cost-of-illness approach is an alternative means of estimating the economic burden of foodborne illness. Using this method, economists add up the directly measurable costs of illness, such as the cost of medical care and the cost of work loss. The problem with this approach is that it completely ignores the far more important losses from pain and suffering and lost utility from a reduced life expectancy. The social cost of a foodborne illness that kills an infant or elderly person will be limited to the medical costs incurred, which may be negligible. This clearly is an underestimate of society's value for these persons. The advantage of this method, however, is that the values used are easily understood by policymakers and, because it employs directly measurable costs, this method can be tailored to specific pathogens and populations of interest.

Recognizing the limitations of direct elicitation of WTP measures and needing measures flexible enough to be tailored to different pathogens, the primary food-safety agencies in the United States (FDA and USDA) use alternative, hybrid means for estimating the costs of foodborne illness. While both use similar methods for medical costs and mortality costs, the agencies have diverged on the means of assessing the economic impact of foodborne illness on other quality-of-life losses. USDA uses a conservative estimate for acute illnesses that includes productivity losses, but not pain and suffering losses or the impact of functional disability losses outside the workplace [12]. FDA uses a more inclusive measure that is based on revealed preference hedonic studies combined with quality-adjusted life year (QALY) loss estimates [7].[3]

In this study, I present estimates based on both methods, though I believe the FDA method yields estimates that more accurately reflect the full scope of costs.

The distribution of costs across cost categories is illustrated in Figure 1 for the QALY (FDA) and productivity (USDA) approaches. Although medical costs and lost life expectancy costs are the same in both cases, the effect of increasing the scope of quality-of-life losses under the QALY approach is evident. Quality-of-life losses make up a larger share of all costs when QALYs are used.

Foodborne illnesses are caused by a variety of pathogens. Each pathogen manifests itself in a unique way. For some, illnesses are likely to be mild with no lasting effects. For others, the corresponding illness is characterized by a high hospitalization and death rate. Also, many have a probability of some long-term health problems [5]. For this reason it is important to estimate costs

Figure 1


[3] The monetized QALY provides an adjusted WTP measure for lost quality of life. Included in this measure are productivity losses (at home and at the workplace) and pain and suffering losses.

separately for each pathogen. The pathogen-specific costs for the major cost categories are illustrated in Table 1. Pathogen differences are clear when shown in this light. Typhoid fever (caused by *Salmonella typhi*) is characterized by relatively high medical costs. Alternatively, those made ill by *Giardia lamblia* have higher quality-of-life losses and those infected with *Vibrio vulnificus* have a large chance of dying from their illness.

Table 1

**COST OF FOODBORNE ILLNESS IN THE UNITED STATES**[a]

| | Hospital Services | Physician Services | Drugs | Deaths | Quality of Life[b] | Total Cost Per Case |
|---|---|---|---|---|---|---|
| **Bacterial** | | | | | | |
| *Bacillus cereus* | 4 | 21 | 3 | 0 | 198 | 226 |
| Botulism, foodborne | 157,703 | 1885 | 37 | 542,012 | 24,726 | 726,362 |
| *Brucella* spp. | 3,692 | 107 | 5 | 60,689 | 6,206 | 70,698 |
| *Campylobacter* spp. | 137 | 33 | 5 | 616 | 8,110 | 8,901 |
| *Clostridium perfringens* | 2 | 21 | 3 | 221 | 263 | 510 |
| *E. coli* O157:H7 | 921 | 54 | 4 | 12,460 | 1,399 | 14,838 |
| *E. coli*, Non-O157 STEC | 6 | 21 | 3 | 0 | 1,309 | 1,339 |
| *E. coli*, Other | 5 | 21 | 3 | 0 | 1,339 | 1,368 |
| *Listeria monocytogenes* | 78,127 | 1541 | 43 | 1,573,209 | 42,222 | 1,695,143 |
| *Salmonella*, Typhi | 21,641 | 816 | 35 | 35,767 | 4,251 | 62,509 |
| *Salmonella*, nontyphoidal | 278 | 35 | 5 | 3,239 | 5,590 | 9,146 |
| *Shigella* spp. | 214 | 34 | 5 | 1,227 | 5,611 | 7,092 |
| Staphylococcus | 103 | 25 | 3 | 85 | 601 | 818 |
| Streptococcus, foodborne | 93 | 24 | 3 | 0 | 2,167 | 2,288 |
| *Vibrio cholerae*, toxigenic | 3,485 | 228 | 16 | 0 | 1,699 | 5,428 |
| *Vibrio vulnificus* | 34,950 | 595 | 42 | 3,009,896 | 243 | 3,045,726 |
| *Vibrio*, other | 152 | 27 | 3 | 19,947 | 1,681 | 21,810 |
| *Yersinia enterocolitica* | 293 | 35 | 5 | 181 | 6,713 | 7,227 |
| **Parasitic** | | | | | | |
| *Cryptosporidium parvum* | 126 | 25 | 3 | 1,834 | 2,436 | 4,424 |
| *Cyclospora cayetanensis* | 19 | 21 | 3 | 0 | 1,489 | 1,531 |
| *Giardia lamblia* | 44 | 22 | 3 | 39 | 3,567 | 3,675 |
| *Toxoplasma gondii* | 1,280 | 49 | 3 | 26,197 | 1,899 | 29,429 |
| *Trichinella spiralis* | 3,224 | 87 | 5 | 0 | 8,548 | 11,864 |
| **Viral** | | | | | | |
| Norwalk-like viruses | 42 | 22 | 3 | 106 | 413 | 586 |
| Rotavirus | 96 | 27 | 3 | 0 | 1,028 | 1,155 |
| Astrovirus | 41 | 22 | 3 | 0 | 1,202 | 1,268 |
| Hepatitis A | 495 | 36 | 3 | 7,540 | 3,119 | 11,193 |
| **Unknown agents** | | | | | | |
| | 76 | 23 | 3 | 429 | 898 | 1,430 |
| **Expected Cost Per Case of Foodborne Illness in the United States** | | | | | | **1,851** |

[a] Costs in this and other tables in this report are as of September 2009.
[b] Using a monetized QALY based on EQ-5D survey instrument.

## FROM FOODBORNE ILLNESS IN THE UNITED STATES

Table 2 demonstrates the total cost of illness for each pathogen in the United States. Although the majority of costs accrue to unknown agents, infection by other well- known pathogens such as *Campylobacter*, *Listeria* and *Salmonella* have large measurable costs. The total cost of foodborne illness to the United States is almost $152 billion a year. Monte Carlo simulations were used to account for uncertainty in estimates. Confidence intervals based on those simulations are also presented.

Table 2

### TOTAL COST OF FOODBORNE ILLNESS IN THE UNITED STATES

| | Cases | Cost Per Case[a] ($) | Total Cost to U.S. Residents ($ Millions) | Confidence Interval 5% | Confidence Interval 95% |
|---|---|---|---|---|---|
| **Bacterial** | | | | | |
| *Bacillus cereus* | 29,439 | 226 | **7** | <1 | 16 |
| Botulism, foodborne | 62 | 726,362 | **45** | 17 | 74 |
| *Brucella* spp. | 818 | 70,698 | **58** | 14 | 101 |
| *Campylobacter* spp. | 2,112,302 | 8,901 | **18,803** | 4,388 | 36,695 |
| *Clostridium perfringens* | 267,403 | 510 | **136** | 33 | 239 |
| *E. coli* O157:H7 | 66,905 | 14,838 | **993** | 296 | 1,689 |
| *E. coli*, Non-O157 STEC | 5,368 | 1,339 | **7** | 2 | 13 |
| *E. coli*, Other | 4,422 | 1,368 | **6** | 1 | 11 |
| *Listeria monocytogenes* | 5,205 | 1,695,143 | **8,823** | 2,277 | 15,365 |
| *Salmonella*, Typhi | 536 | 62,509 | **34** | 16 | 51 |
| *Salmonella*, nontyphoidal | 1,597,411 | 9,146 | **14,609** | 3,185 | 29,091 |
| *Shigella* spp. | 96,686 | 7,092 | **686** | 124 | 1,519 |
| Staphylococcus | 199,121 | 818 | **163** | 54 | 271 |
| Streptococcus, foodborne | 54,789 | 2,288 | **125** | 31 | 220 |
| *Vibrio cholerae*, toxigenic | 52 | 5,428 | **<1** | <1 | <1 |
| *Vibrio vulnificus* | 51 | 3,045,726 | **154** | 33 | 275 |
| *Vibrio*, other | 5,511 | 21,810 | **120** | 25 | 215 |
| *Yersinia enterocolitica* | 93,321 | 7,227 | **674** | 150 | 1,369 |
| **Parasitic** | | | | | |
| *Cryptosporidium parvum* | 46,978 | 4,424 | **208** | 44 | 421 |
| *Cyclospora cayetanensis* | 32,322 | 1,531 | **49** | 11 | 88 |
| *Giardia lamblia* | 175,033 | 3,675 | **643** | 96 | 1,423 |
| *Toxoplasma gondii* | 121,048 | 29,429 | **3,562** | 855 | 6,273 |
| *Trichinella spiralis* | 56 | 11,864 | **1** | <1 | 1 |
| **Viral** | | | | | |
| Norwalk-like viruses | 9,899,026 | 586 | **5,802** | 1,691 | 9,885 |
| Rotavirus | 41,963 | 1,155 | **48** | 14 | 86 |
| Astrovirus | 41,963 | 1,268 | **53** | 9 | 119 |
| Hepatitis A | 906 | 11,193 | **10** | 2 | 18 |
| **Unknown agents** | | | | | |
| | 67,012,102 | 1,430 | **95,806** | 25,242 | 166,564 |
| **All Illnesses** | 81,910,799 | 1,851 | **151,626** | 38,987 | 264,825 |

[a] Using a monetized QALY based on EQ-5D survey instrument.

Table 3 provides a summary of costs using both the QALY and productivity loss approaches. In addition to mean costs, which increase from $102.7 billion to $151.6 billion when the more inclusive QALY measure is used, I also include 90% confidence intervals to account for uncertainty. Notably, while the mean QALY measure is higher, there is also more uncertainty associated with it. On the one hand, the productivity measure does not include a measure of lost utility from pain and suffering, but, on the other, the data used to derive the estimates (employment and compensation cost data from the Bureau of Labor Statistics) are more certain.

Table 3

**HEALTH-RELATED COSTS FROM FOODBORNE ILLNESS IN THE UNITED STATES**

| Measure of Lost Utility | Mean Cost ($ millions) | CI | | Cost Per Illness ($) | CI | |
|---|---|---|---|---|---|---|
| | | 5% | 95% | | 5% | 95% |
| Monetized QALY | 151,626 | 38,987 | 264,825 | 1,851 | 478 | 3,227 |
| Productivity Proxy | 102,708 | 64,083 | 141,382 | 1,261 | 788 | 1,733 |

## The Cost of Foodborne Illness Across States

In addition to understanding the burden of foodborne illness for the nation as a whole, it is also often useful to understand the impact of these illnesses on individual states. Differences in wages, costs of medical care, and exposure to pathogens all affect the cost of illness for a particular state. Table 4 provides estimates of the economic cost of foodborne illness for the states using the QALY approach. Total costs range from $245 million in Wyoming to $18.6 billion in California. As expected, larger states have higher total costs. The cost per case of foodborne illness is presented in the last column of Table 4. Here, real differences in state costs are more evident. Lower medical costs and a less harmful mix of pathogens lead to a cost per case of only $1,731 in Kentucky. Alternatively, greater exposure to higher cost pathogens leads to costs of $2,008 per case in Hawaii. The ability to differentiate costs for the states is limited in the QALY model, however. Differences in valuation of lost quality of life are likely to exist, but have not been incorporated into the model at this point. Inclusion of such values would almost certainly lead to even more differentiation of costs across the states.

By contrast, state differences in costs are more evident when the productivity model is used. Figure 2 illustrates the cost per case of foodborne illness for medical costs, productivity losses, and total costs. Omitting the District of Columbia (which experiences extremely high productivity losses because of the large number of commuters from Virginia and Maryland), the total cost per case of foodborne illness is between $1,064 in Kentucky and $1,506 in Connecticut. The maps in Figure 2 reveal other interesting facts. Medical costs are lowest in the Great Plains states, while productivity costs are lower in the South. Alternatively, both medical costs and productivity losses are relatively high in California and the Northeast.

Table 4

## ANNUAL HEALTH-RELATED COSTS OF FOODBORNE ILLNESS FOR EACH STATE[a]

| | Medical Costs ($ millions) | Quality of Life Losses ($ millions) | Lost Life Expectancy ($ millions) | Total Cost ($ millions) | Cost per Case ($) |
|---|---|---|---|---|---|
| Alabama | 139 | 1,462 | 720 | 2,321 | 1,834 |
| Alaska | 23 | 206 | 107 | 336 | 1,829 |
| Arizona | 203 | 1,821 | 919 | 2,943 | 1,829 |
| Arkansas | 78 | 952 | 454 | 1,484 | 1,899 |
| California | 1,484 | 11,129 | 6,000 | 18,613 | 1,877 |
| Colorado | 151 | 1,449 | 737 | 2,336 | 1,814 |
| Connecticut | 118 | 1,098 | 677 | 1,893 | 1,949 |
| District of Columbia | 22 | 183 | 109 | 314 | 1,935 |
| Delaware | 24 | 264 | 129 | 418 | 1,805 |
| Florida | 727 | 5,996 | 3,075 | 9,799 | 1,984 |
| Georgia | 272 | 2,946 | 1,503 | 4,721 | 1,876 |
| Hawaii | 54 | 417 | 239 | 710 | 2,008 |
| Idaho | 32 | 438 | 212 | 682 | 1,747 |
| Illinois | 458 | 3,995 | 2,035 | 6,487 | 1,836 |
| Indiana | 168 | 1,915 | 985 | 3,069 | 1,778 |
| Iowa | 72 | 942 | 478 | 1,491 | 1,805 |
| Kansas | 80 | 857 | 407 | 1,343 | 1,764 |
| Kentucky | 111 | 1,274 | 605 | 1,990 | 1,731 |
| Louisiana | 150 | 1,454 | 710 | 2,314 | 1,859 |
| Maine | 37 | 407 | 239 | 683 | 1,877 |
| Maryland | 126 | 1,755 | 1,004 | 2,884 | 1,871 |
| Massachusetts | 210 | 2,100 | 1,164 | 3,474 | 1,921 |
| Michigan | 320 | 3,069 | 1,569 | 4,958 | 1,776 |
| Minnesota | 142 | 1,610 | 795 | 2,546 | 1,789 |
| Mississippi | 93 | 1,011 | 482 | 1,586 | 1,932 |
| Missouri | 201 | 1,819 | 889 | 2,909 | 1,812 |
| Montana | 20 | 294 | 142 | 457 | 1,762 |
| Nebraska | 47 | 545 | 289 | 881 | 1,812 |
| Nevada | 89 | 707 | 358 | 1,154 | 1,793 |
| New Hampshire | 38 | 404 | 239 | 681 | 1,892 |
| New Jersey | 389 | 2,676 | 1,530 | 4,595 | 1,918 |
| New Mexico | 58 | 603 | 301 | 963 | 1,820 |
| New York | 657 | 6,113 | 3,605 | 10,375 | 1,930 |
| North Carolina | 234 | 2,793 | 1,460 | 4,487 | 1,866 |
| North Dakota | 14 | 195 | 103 | 312 | 1,769 |
| Ohio | 374 | 3,551 | 1,918 | 5,843 | 1,837 |
| Oklahoma | 102 | 1,124 | 541 | 1,767 | 1,796 |
| Oregon | 96 | 1,121 | 600 | 1,817 | 1,813 |
| Pennsylvania | 463 | 3,908 | 2,345 | 6,716 | 1,949 |
| Rhode Island | 34 | 336 | 201 | 571 | 1,917 |
| South Carolina | 143 | 1,421 | 738 | 2,302 | 1,937 |
| South Dakota | 18 | 257 | 130 | 405 | 1,850 |
| Tennessee | 170 | 1,859 | 936 | 2,965 | 1,798 |
| Texas | 756 | 7,107 | 3,455 | 11,317 | 1,805 |
| Utah | 65 | 757 | 363 | 1,185 | 1,742 |
| Vermont | 15 | 197 | 108 | 321 | 1,850 |
| Virginia | 221 | 2,380 | 1,235 | 3,835 | 1,840 |
| Washington | 166 | 1,909 | 994 | 3,069 | 1,781 |
| West Virginia | 44 | 552 | 311 | 907 | 1,816 |
| Wisconsin | 157 | 1,792 | 943 | 2,892 | 1,864 |
| Wyoming | 14 | 159 | 72 | 245 | 1,738 |

[a] Using a monetized QALY based on EQ-5D survey instrument

**Figure 2**

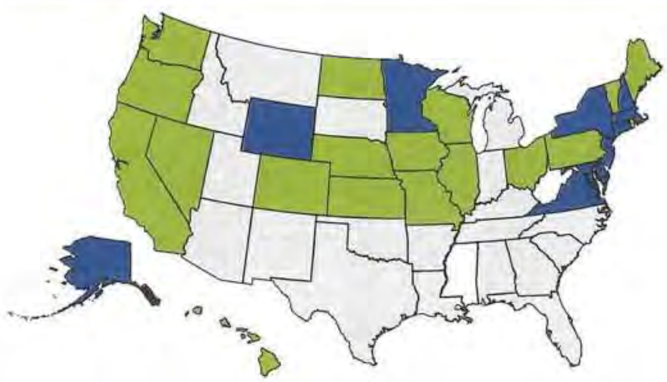
### STATE DIFFERENCES IN THE COST PER CASE OF FOODBORNE ILLNESS

*(known pathogens using the productivity proxy)*

**Medical Costs**

Typical medical costs from a case of foodborne illness range from $78 in Montana to $162 in New Jersey. A sizable share of the difference in values is due to geographic disparities in physician and hospital charges. Differences in the mix of pathogens causing illness account for the remainder of the disparity in medical costs across the states (due to differences in illness severity).

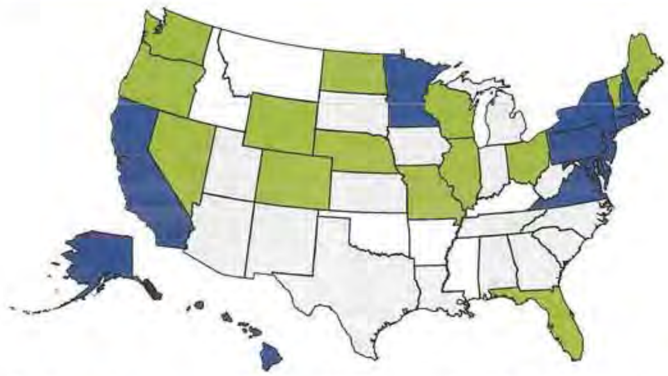
**Cost per Case:** $70 to $90 | $90 to $110 | $110 to $130 | $130+



**Productivity Losses**

The average productivity loss from a case of foodborne illness is between $377 (Mississippi) and $924 (Delaware). Differences in wages, benefits, and employment account for some of the disparity. The selection of pathogens causing illness also has an effect. States with high employment of other states' residents have higher productivity losses.

**Cost per Case:** $300 to $400 | $400 to $500 | $500 to $600 | $600+



**Total Cost per Case**

The total cost of foodborne illness is the sum of medical costs, productivity losses, and utility losses from premature mortality. Residents of states in the northeast experience the highest costs from foodborne illness ($1,506 in Connecticut), while residents in the central portion of the country experience a lower cost of illness ($1,064 in Kentucky).

**Cost per Case:** $1,000 to $1,100 | $1,100 to $1,200 | $1,200 to $1,300 | $1,300+

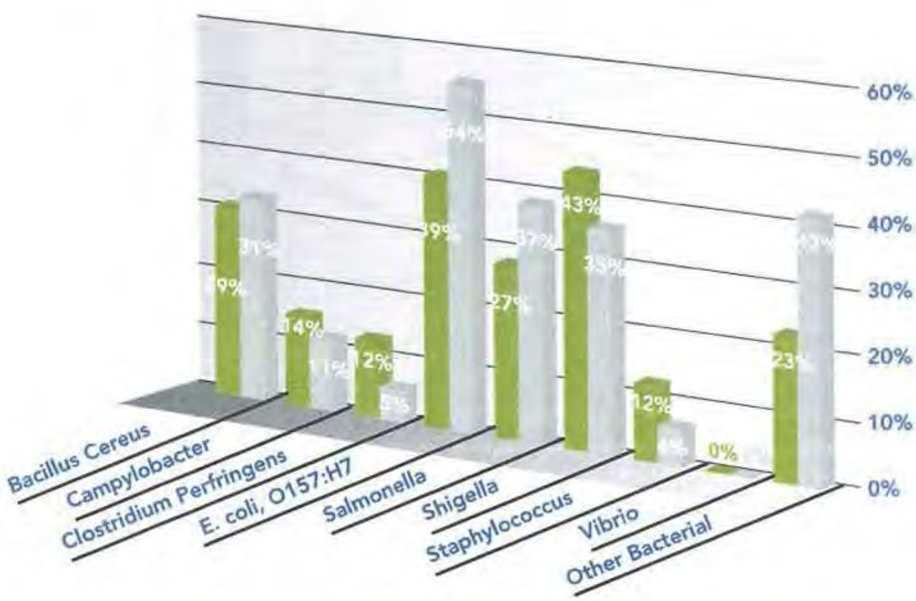
## Produce-Related Costs

Given the fact that produce has been linked to the largest number of outbreaks involving FDA-regulated foods, it is useful to estimate the cost of illness linked to these commodities. The measured differences in costs across the states are due to both (1) variation of state medical and productivity costs and (2) state-level differences in the incidence of illness from each pathogen. Given the close association of certain pathogens with identified product categories (e.g. fresh spinach and *E. coli* O157:H7), it stands to reason that costs will also vary across product categories. In this section I evaluate produce-related costs by isolating the proportion of illnesses attributable to contaminated produce for each pathogen.

Figure 3 illustrates the number of bacterial outbreaks and illnesses attributable to produce, based on 2003-2007 data from the CDC's Foodborne Disease Outbreak Surveillance System [2]. Outbreaks in which no food was implicated were dropped from the analysis. An outbreak was considered to be associated with produce if at least one of the vehicles of contamination was a fresh, canned, or processed produce item. While most of the outbreaks have been linked to "fresh produce" (items like leafy greens and tomatoes that are eaten raw), the available outbreak data does not distinguish between fresh, canned, and processed items. Illnesses associated with each outbreak were divided evenly between the vehicles implicated in the outbreak. The number of illnesses attributable to produce products was estimated separately for nine specific pathogens and four pathogen categories.

### Figure 3

**% OF OUTBREAKS AND ILLNESSES ATTRIBUTABLE TO PRODUCE**
*(bacterial pathogens)*



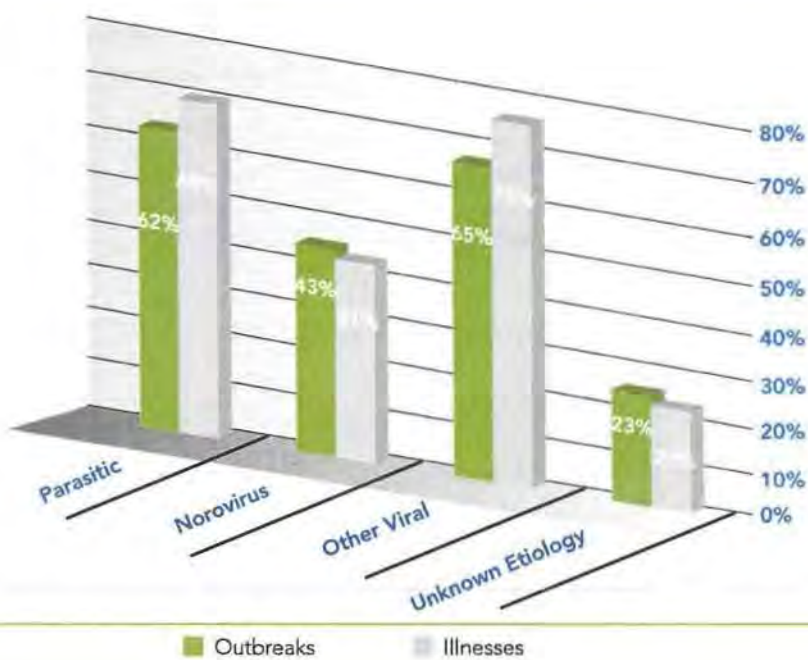

Outbreaks Illnesses

The incidence of illness from a pathogen that has contaminated a produce item varied widely across the bacterial pathogens examined. Understandably, no *Vibrio* outbreaks were associated with produce (*Vibrio* is generally found in shellfish). At the other extreme, 39% of *E. coli* outbreaks and 54% of *E. coli* illnesses were attributable to produce.

Outbreaks and illnesses attributable to non-bacterial etiologies are shown in Figure 4. Produce is a common vehicle for Norovirus, the agent most commonly found in foodborne illness outbreaks, and other viruses. Surprisingly, so are parasitic pathogens (though the small number of identified parasite outbreaks suggests that these numbers are less robust). Outbreaks in which a pathogen was not identified, but a food vehicle was, are relatively unlikely to be attributable to produce.

Figure 4

**% OF OUTBREAKS AND ILLNESSES ATTRIBUTABLE TO PRODUCE**
*(non-bacterial etiologies)*




The burden of foodborne illness attributable to produce is exhibited in Table 5. Produce (fresh, canned, and processed) accounts for roughly one quarter of all foodborne illnesses. Illnesses vary across the states due to both population variations and differences in incidence of illness. The cost per case is somewhat higher for produce-attributable illnesses ($1,961 vs. $1,851 for all products) than for illnesses caused by pathogens delivered through other vehicles. This difference is due to the relatively higher proportion of illnesses attributable to produce for high- cost etiologies (i.e. *E. coli*), opposed to low- cost etiologies (i.e. those with an unknown etiology).

Table 5

### COSTS FROM PRODUCE RELATED FOODBORNE ILLNESS

| State | Illnesses | Total Cost ($ millions) | Cost Per Case ($) |
|---|---|---|---|
| **United States** | **19,677,547** | **38,593** | **1,961** |
| Alabama | 303,801 | 580 | 1,908 |
| Alaska | 44,219 | 85 | 1,913 |
| Arizona | 384,868 | 745 | 1,936 |
| Arkansas | 189,032 | 402 | 2,125 |
| California | 2,372,499 | 4,678 | 1,972 |
| Colorado | 309,605 | 585 | 1,890 |
| Connecticut | 234,194 | 497 | 2,121 |
| District of Columbia | 39,296 | 82 | 2,082 |
| Delaware | 55,536 | 104 | 1,869 |
| Florida | 1,201,633 | 2,551 | 2,123 |
| Georgia | 607,588 | 1,204 | 1,982 |
| Hawaii | 85,144 | 186 | 2,184 |
| Idaho | 94,242 | 171 | 1,812 |
| Illinois | 847,771 | 1,620 | 1,910 |
| Indiana | 413,126 | 760 | 1,840 |
| Iowa | 199,503 | 380 | 1,903 |
| Kansas | 182,832 | 330 | 1,806 |
| Kentucky | 275,213 | 483 | 1,756 |
| Louisiana | 298,568 | 578 | 1,935 |
| Maine | 87,586 | 177 | 2,020 |
| Maryland | 369,024 | 737 | 1,998 |
| Massachusetts | 437,321 | 903 | 2,065 |
| Michigan | 667,476 | 1,220 | 1,827 |
| Minnesota | 345,183 | 646 | 1,872 |
| Mississippi | 198,383 | 405 | 2,043 |
| Missouri | 386,039 | 724 | 1,876 |
| Montana | 62,528 | 114 | 1,828 |
| Nebraska | 116,952 | 224 | 1,912 |
| Nevada | 153,589 | 282 | 1,838 |
| New Hampshire | 86,194 | 176 | 2,036 |
| New Jersey | 572,976 | 1,167 | 2,037 |
| New Mexico | 126,914 | 240 | 1,889 |
| New York | 1,296,528 | 2,706 | 2,087 |
| North Carolina | 578,894 | 1,142 | 1,973 |
| North Dakota | 42,367 | 78 | 1,847 |
| Ohio | 762,576 | 1,472 | 1,930 |
| Oklahoma | 235,815 | 436 | 1,851 |
| Oregon | 241,280 | 463 | 1,917 |
| Pennsylvania | 828,152 | 1,747 | 2,109 |
| Rhode Island | 71,611 | 148 | 2,072 |
| South Carolina | 286,587 | 592 | 2,064 |
| South Dakota | 53,239 | 105 | 1,978 |
| Tennessee | 394,631 | 734 | 1,859 |
| Texas | 1,502,414 | 2,788 | 1,856 |
| Utah | 163,794 | 293 | 1,790 |
| Vermont | 42,267 | 84 | 1,992 |
| Virginia | 500,395 | 965 | 1,929 |
| Washington | 412,800 | 765 | 1,854 |
| West Virginia | 119,035 | 227 | 1,909 |
| Wisconsin | 377,174 | 753 | 1,997 |
| Wyoming | 33,818 | 60 | 1,766 |

## Discussion: Why the Cost of Foodborne Illness Matters

To some, the use of economic values to characterize pain, suffering, and death is a disturbing exercise that is ethically suspect. It has been argued that food safety is a right that should not have a price tag attached to it and that the justification of spending should be based on consumer willingness to pay for safety with little regard for the relative cost-effectiveness of controls. In this section, I address each of these concerns and conclude with this economist's view of how the values presented in this report can be used in a policy context.

### The Ethics of Valuing Life/Pain and Suffering

In this report, the value of a statistical life (VSL) provides the basis for evaluating the economic cost of both death and pain and suffering. The economic concept of the VSL is often misunderstood. Economists do not try to make the argument that an individual's life has an intrinsic value that we can measure. Instead, what we try to do in economics is figure out how much people are willing to pay to eliminate a risk of mortality (*not* mortality itself). Implicitly, we make these trade-offs all the time. For example, do we want to pay $1000 more for a car with a certain safety feature? Few of us buy every safety feature available. Why? We forego certain safety features because we'd rather spend the money on something else, such as taking a vacation. More generally, we make choices between risk and utility all the time. We choose to drive to a party (a very dangerous prospect) because we think the fun from the party is worth the risk of operating a motor vehicle. For policy purposes, we try to capture society's preferences for risk using the recognition that people make choices involving risk. A simple example: If the average person requires a $700 increase in salary to accept a 1/10,000 chance of being killed on the job in any given year, the equation is: $700 = 1/10,000*Death. This implies that Death = $7 million. So, in essence, the value of statistical life is the average citizen's value for reducing a risk to life, not the intrinsic value of life.

It is obvious that there are limitations to this approach; for example, if the people who are the basis for these values have few job options, they may be willing to take a small salary increase to accept a high risk of being killed on their job, whereas people who have more job options might insist on much more money to accept that risk. Similarly, parents may be willing to pay much more to avoid a risk of death for their child than they would be to pay to reduce their own risks. From a policy perspective, however, despite these and other recognized problems with this approach, by using values- based consumer preferences, the policy-maker presumably more closely aligns policy decisions with the preferences of the citizens she represents. It is of course recognized that an approach to deriving a value of statistical life that is less dependent on labor market conditions, could result in higher VSL estimates. Nevertheless, currently available alternatives are subject to greater biases than those found in VSL estimates.

### Food Safety is a Right

Another argument against using economic values to inform food safety policy is that every individual has the right to be free from foodborne pathogens. Thus, if food safety is a right, economic evaluation is unnecessary and the goal should be to eliminate foodborne illness at all cost. In support of this argument, one could point to, the Federal Food Drug and Cosmetic Act of 1938 (FD&C Act), which states: "A food shall be deemed to be adulterated… [i]f it bears or contains any poisonous or deleterious substance which may render it injurious to health." Sec. 402. [21 USC §342]. Contamination of a product with harmful pathogens can lead to that product being deemed adulterated. So then, if safe food is a right, why do we still have foodborne illness? The answer is that: (1) the presence of pathogens in food is a complicated problem involving numerous, not fully understood vectors of contamination; (2) society has limited resources with which to solve the problems it faces; and (3) it has limited information on the extent, causes, and adequacy of methods available to prevent foodborne disease. Economic analysis can help us set priorities regarding which foodborne illness problems to tackle first—even as we continue to strive to achieve the ultimate goal of eliminating these illnesses.

Given that we have to make choices and set priorities, the use of economic analyses designed to reflect consumer preferences is a reasonable way to make those choices. It is recognized, however, that there are likely certain benefits of reducing foodborne illness that have not been fully characterized and monetized—for example, there likely are long-term medical impacts of infection by some pathogens that have not been characterized, and that if fully understood, would result in significantly higher estimated costs. Such costs, while not presently known or monetized, should not be dismissed, and precautionary steps may be warranted to avoid them in appropriate cases.

## Conclusion

In this report, I have demonstrated that, using what I conclude is the best currently-available measure, the mean economic cost of foodborne illness is approximately $152 billion (95% CI $39-$265 billion), of which almost $39 billion can be attributed to produce. These values certainly have importance in terms of placing the problem of food safety and, specifically, the problem of produce safety in the proper perspective. This is a large problem that deserves the attention of policymakers.

This does not mean, however, that any program that costs a fraction of this value is justified by the overall magnitude of the problem. From an economic perspective, a program is worth its cost if the last dollar invested yields more than a dollar in benefits to society. We must be cautious, of course, not to overstate the precision of these cost estimates; they can be an important and valuable—but imperfect—tool available to help make decisions and set priorities on food safety. In mid-19th century London, John Snow, operating on incomplete information, removed the handle of a well in order to bring an end to a cholera epidemic. Similarly, in dealing with foodborne illness, policy makers facing imperfect information and on-going foodborne disease may well rationally decide, to take a similarly dramatic step to reduce pathogen levels in the nation's food supply. By providing more comprehensive cost-per-case values for all pathogens and specifically for produce-related illnesses, however, this report can contribute to assessments about whether current food safety proposals make sense, or what priority should be placed upon those proposals. The cost of foodborne illness is significantly greater in this report than in some past studies, but only because this study included costs of all pathogens and a more comprehensive measure of economic cost. It is my hope that the improvements made here will lead to better decision-making, both at the legislative and regulatory level.



# FROM FOODBORNE ILLNESS IN THE UNITED STATES

## APPENDIX A: State Rankings

As demonstrated above, the burden of foodborne illness falls unevenly across the states. The following tables provide state rankings for the number of illnesses and costs associated with these illnesses. Tables are provided for both all illnesses and those illnesses attributable to a produce vehicle.

### Table A1

#### NUMBER OF FOODBORNE ILLNESSES

| Rank | State | Illnesses | Rank | State | Illnesses |
|---|---|---|---|---|---|
| | **The United States** | **81,910,799** | | | |
| 1. | California | 9,914,868 | 27. | Oregon | 1,002,404 |
| 2. | Texas | 6,271,730 | 28. | Oklahoma | 983,958 |
| 3. | New York | 5,375,122 | 29. | Connecticut | 971,254 |
| 4. | Florida | 4,939,310 | 30. | Iowa | 826,178 |
| 5. | Illinois | 3,533,862 | 31. | Mississippi | 820,890 |
| 6. | Pennsylvania | 3,446,085 | 32. | Arkansas | 781,266 |
| 7. | Ohio | 3,181,257 | 33. | Kansas | 761,514 |
| 8. | Michigan | 2,792,153 | 34. | Utah | 680,497 |
| 9. | Georgia | 2,516,209 | 35. | Nevada | 643,769 |
| 10. | North Carolina | 2,404,537 | 36. | New Mexico | 529,048 |
| 11. | New Jersey | 2,395,361 | 37. | West Virginia | 499,373 |
| 12. | Virginia | 2,084,734 | 38. | Nebraska | 486,299 |
| 13. | Massachusetts | 1,808,576 | 39. | Idaho | 390,457 |
| 14. | Indiana | 1,726,560 | 40. | Maine | 363,856 |
| 15. | Washington | 1,722,587 | 41. | New Hampshire | 359,750 |
| 16. | Tennessee | 1,649,454 | 42. | Hawaii | 353,274 |
| 17. | Arizona | 1,609,026 | 43. | Rhode Island | 297,778 |
| 18. | Missouri | 1,605,538 | 44. | Montana | 259,305 |
| 19. | Wisconsin | 1,551,417 | 45. | Delaware | 231,396 |
| 20. | Maryland | 1,541,601 | 46. | South Dakota | 218,910 |
| 21. | Minnesota | 1,423,779 | 47. | Alaska | 183,880 |
| 22. | Colorado | 1,288,188 | 48. | North Dakota | 176,566 |
| 23. | Alabama | 1,265,600 | 49. | Vermont | 173,536 |
| 24. | Louisiana | 1,244,347 | 50. | District of Columbia | 162,317 |
| 25. | South Carolina | 1,188,745 | 51. | Wyoming | 140,718 |
| 26. | Kentucky | 1,149,810 | | | |

Notes:

1. For illnesses from pathogens not reported to CDC, the numbers above only reflect population trends, not trends in the incidence of foodborne illness.
2. For illnesses from pathogens reported to CDC, the number of illnesses for each pathogen is the product of the CDC report and the Mead et al. (1999) underreporting multiplier .
3. The total number of illnesses reported here differs from the number reported by Mead et al. (1999). Adjustments were made based on changes in incidence of illness or, where such data does was not available, based on changes in state populations. See Appendix B for more detail.

# FROM FOODBORNE ILLNESS IN THE UNITED STATES

Table A2

## NUMBER OF PRODUCE-RELATED FOODBORNE ILLNESSES

| Rank | State | Illnesses |
|---|---|---|
| | **The United States** | **19,677,547** |
| 1. | California | 2,372,499 |
| 2. | Texas | 1,502,414 |
| 3. | New York | 1,296,528 |
| 4. | Florida | 1,201,633 |
| 5. | Illinois | 847,771 |
| 6. | Pennsylvania | 828,152 |
| 7. | Ohio | 762,576 |
| 8. | Michigan | 667,476 |
| 9. | Georgia | 607,588 |
| 10. | North Carolina | 578,894 |
| 11. | New Jersey | 572,976 |
| 12. | Virginia | 500,395 |
| 13. | Massachusetts | 437,321 |
| 14. | Indiana | 413,126 |
| 15. | Washington | 412,800 |
| 16. | Tennessee | 394,631 |
| 17. | Missouri | 386,039 |
| 18. | Arizona | 384,868 |
| 19. | Wisconsin | 377,174 |
| 20. | Maryland | 369,024 |
| 21. | Minnesota | 345,183 |
| 22. | Colorado | 309,605 |
| 23. | Alabama | 303,801 |
| 24. | Louisiana | 298,568 |
| 25. | South Carolina | 286,587 |
| 26. | Kentucky | 275,213 |
| 27. | Oregon | 241,280 |
| 28. | Oklahoma | 235,815 |
| 29. | Connecticut | 234,194 |
| 30. | Iowa | 199,503 |
| 31. | Mississippi | 198,383 |
| 32. | Arkansas | 189,032 |
| 33. | Kansas | 182,832 |
| 34. | Utah | 163,794 |
| 35. | Nevada | 153,589 |
| 36. | New Mexico | 126,914 |
| 37. | West Virginia | 119,035 |
| 38. | Nebraska | 116,952 |
| 39. | Idaho | 94,242 |
| 40. | Maine | 87,586 |
| 41. | New Hampshire | 86,194 |
| 42. | Hawaii | 85,144 |
| 43. | Rhode Island | 71,611 |
| 44. | Montana | 62,528 |
| 45. | Delaware | 55,536 |
| 46. | South Dakota | 53,239 |
| 47. | Alaska | 44,219 |
| 48. | North Dakota | 42,367 |
| 49. | Vermont | 42,267 |
| 50. | District of Columbia | 39,296 |
| 51. | Wyoming | 33,818 |

Notes:

1. Produce is defined broadly to include fresh, canned and processed produce items.
2. The number of produce-related foodborne illnesses is estimated as the product of the total number of foodborne illnesses and the proportion of illnesses in outbreaks that are associated with a produce vehicle of transmission.

Table A3

## TOTAL COST OF FOODBORNE ILLNESS

| Rank | State | Total Cost ($ millions) | Rank | State | Total Cost ($ millions) |
|---|---|---|---|---|---|
| | **The United States** | **152,369** | | | |
| 1. | California | 18,613 | 27. | Connecticut | 1,893 |
| 2. | Texas | 11,317 | 28. | Oregon | 1,817 |
| 3. | New York | 10,375 | 29. | Oklahoma | 1,767 |
| 4. | Florida | 9,799 | 30. | Mississippi | 1,586 |
| 5. | Pennsylvania | 6,716 | 31. | Iowa | 1,491 |
| 6. | Illinois | 6,487 | 32. | Arkansas | 1,484 |
| 7. | Ohio | 5,843 | 33. | Kansas | 1,343 |
| 8. | Michigan | 4,958 | 34. | Utah | 1,185 |
| 9. | Georgia | 4,721 | 35. | Nevada | 1,154 |
| 10. | New Jersey | 4,595 | 36. | New Mexico | 963 |
| 11. | North Carolina | 4,487 | 37. | West Virginia | 907 |
| 12. | Virginia | 3,835 | 38. | Nebraska | 881 |
| 13. | Massachusetts | 3,474 | 39. | Hawaii | 710 |
| 14. | Indiana | 3,069 | 40. | Maine | 683 |
| 15. | Washington | 3,069 | 41. | Idaho | 682 |
| 16. | Tennessee | 2,965 | 42. | New Hampshire | 681 |
| 17. | Arizona | 2,943 | 43. | Rhode Island | 571 |
| 18. | Missouri | 2,909 | 44. | Montana | 457 |
| 19. | Wisconsin | 2,892 | 45. | Delaware | 418 |
| 20. | Maryland | 2,884 | 46. | South Dakota | 405 |
| 21. | Minnesota | 2,546 | 47. | Alaska | 336 |
| 22. | Colorado | 2,336 | 48. | Vermont | 321 |
| 23. | Alabama | 2,321 | 49. | District of Columbia | 314 |
| 24. | Louisiana | 2,314 | 50. | North Dakota | 312 |
| 25. | South Carolina | 2,302 | 51. | Wyoming | 245 |
| 26. | Kentucky | 1,990 | | | |

Note:

The total cost of foodborne illness is the sum of medical costs, quality of life losses (including lost productivity), and lost life expectancy. Quality of life and lost life expectancy losses are estimated using revealed preference values for risk avoidance.

Table A4

## TOTAL COST OF FOODBORNE ILLNESS BY FOOD SOURCE OF CONTAMINATION

| Rank | State | Cost ($ millions) Produce | Cost ($ millions) Other |
|---|---|---|---|
| | **The United States** | **38,593** | **113,775** |
| 1. | California | 4,678 | 13,935 |
| 2. | Texas | 2,788 | 8,530 |
| 3. | New York | 2,706 | 7,669 |
| 4. | Florida | 2,551 | 7,249 |
| 5. | Pennsylvania | 1,747 | 4,970 |
| 6. | Illinois | 1,620 | 4,867 |
| 7. | Ohio | 1,472 | 4,371 |
| 8. | Michigan | 1,220 | 3,738 |
| 9. | Georgia | 1,204 | 3,517 |
| 10. | New Jersey | 1,167 | 3,428 |
| 11. | North Carolina | 1,142 | 3,344 |
| 12. | Virginia | 965 | 2,870 |
| 13. | Massachusetts | 903 | 2,571 |
| 14. | Washington | 765 | 2,303 |
| 15. | Indiana | 760 | 2,309 |
| 16. | Wisconsin | 753 | 2,138 |
| 17. | Arizona | 745 | 2,197 |
| 18. | Maryland | 737 | 2,147 |
| 19. | Tennessee | 734 | 2,232 |
| 20. | Missouri | 724 | 2,185 |
| 21. | Minnesota | 646 | 1,900 |
| 22. | South Carolina | 592 | 1,711 |
| 23. | Colorado | 585 | 1,751 |
| 24. | Alabama | 580 | 1,742 |
| 25. | Louisiana | 578 | 1,736 |
| 26. | Connecticut | 497 | 1,396 |
| 27. | Kentucky | 483 | 1,507 |
| 28. | Oregon | 463 | 1,355 |
| 29. | Oklahoma | 436 | 1,331 |
| 30. | Mississippi | 405 | 1,180 |
| 31. | Arkansas | 402 | 1,082 |
| 32. | Iowa | 380 | 1,112 |
| 33. | Kansas | 330 | 1,013 |
| 34. | Utah | 293 | 892 |
| 35. | Nevada | 282 | 872 |
| 36. | New Mexico | 240 | 723 |
| 37. | West Virginia | 227 | 680 |
| 38. | Nebraska | 224 | 657 |
| 39. | Hawaii | 186 | 524 |
| 40. | Maine | 177 | 506 |
| 41. | New Hampshire | 176 | 505 |
| 42. | Idaho | 171 | 511 |
| 43. | Rhode Island | 148 | 422 |
| 44. | Montana | 114 | 342 |
| 45. | South Dakota | 105 | 300 |
| 46. | Delaware | 104 | 314 |
| 47. | Alaska | 85 | 252 |
| 48. | Vermont | 84 | 237 |
| 49. | District of Columbia | 82 | 232 |
| 50. | North Dakota | 78 | 234 |
| 51. | Wyoming | 60 | 185 |

Table A5

## TOTAL COST PER CASE OF FOODBORNE ILLNESS

| Rank | State | Cost per Case ($) | Rank | State | Cost per Case ($) |
|---|---|---|---|---|---|
| | **The United States** | **1,851** | | | |
| 1. | Hawaii | 2,008 | 27. | Alaska | 1,829 |
| 2. | Florida | 1,984 | 28. | Arizona | 1,829 |
| 3. | Connecticut | 1,949 | 29. | New Mexico | 1,820 |
| 4. | Pennsylvania | 1,949 | 30. | West Virginia | 1,816 |
| 5. | South Carolina | 1,937 | 31. | Colorado | 1,814 |
| 6. | District of Columbia | 1,935 | 32. | Oregon | 1,813 |
| 7. | Mississippi | 1,932 | 33. | Missouri | 1,812 |
| 8. | New York | 1,930 | 34. | Nebraska | 1,812 |
| 9. | Massachusetts | 1,921 | 35. | Delaware | 1,805 |
| 10. | New Jersey | 1,918 | 36. | Iowa | 1,805 |
| 11. | Rhode Island | 1,917 | 37. | Texas | 1,805 |
| 12. | Arkansas | 1,899 | 38. | Tennessee | 1,798 |
| 13. | New Hampshire | 1,892 | 39. | Oklahoma | 1,796 |
| 14. | California | 1,877 | 40. | Nevada | 1,793 |
| 15. | Maine | 1,877 | 41. | Minnesota | 1,789 |
| 16. | Georgia | 1,876 | 42. | Washington | 1,781 |
| 17. | Maryland | 1,871 | 43. | Indiana | 1,778 |
| 18. | North Carolina | 1,866 | 44. | Michigan | 1,776 |
| 19. | Wisconsin | 1,864 | 45. | North Dakota | 1,769 |
| 20. | Louisiana | 1,859 | 46. | Kansas | 1,764 |
| 21. | Vermont | 1,850 | 47. | Montana | 1,762 |
| 22. | South Dakota | 1,850 | 48. | Idaho | 1,747 |
| 23. | Virginia | 1,840 | 49. | Utah | 1,742 |
| 24. | Ohio | 1,837 | 50. | Wyoming | 1,738 |
| 25. | Illinois | 1,836 | 51. | Kentucky | 1,731 |
| 26. | Alabama | 1,834 | | | |

**Note:**

The total cost per case is the sum of the cost per case of medical costs, quality of life losses (including lost productivity), and lost life expectancy. Quality of life and lost life expectancy losses are estimated using revealed preference values for risk avoidance.

Table A6

## TOTAL COST PER CASE BY FOOD SOURCE OF CONTAMINATION

| Rank | State | Cost per Case ($) Produce | Cost per Case ($) Other | Rank | State | Cost per Case ($) Produce | Cost per Case ($) Other |
|---|---|---|---|---|---|---|---|
| | **The United States** | **1,961** | **1,816** | | | | |
| 1. | Hawaii | 2,184 | 1,953 | 27. | Alaska | 1,913 | 1,803 |
| 2. | Arkansas | 2,125 | 1,827 | 28. | Nebraska | 1,912 | 1,780 |
| 3. | Florida | 2,123 | 1,939 | 29. | Illinois | 1,910 | 1,812 |
| 4. | Connecticut | 2,121 | 1,895 | 30. | West Virginia | 1,909 | 1,787 |
| 5. | Pennsylvania | 2,109 | 1,898 | 31. | Alabama | 1,908 | 1,811 |
| 6. | New York | 2,087 | 1,880 | 32. | Iowa | 1,903 | 1,774 |
| 7. | District of Columbia | 2,082 | 1,888 | 33. | Colorado | 1,890 | 1,790 |
| 8. | Rhode Island | 2,072 | 1,867 | 34. | New Mexico | 1,889 | 1,798 |
| 9. | Massachusetts | 2,065 | 1,875 | 35. | Missouri | 1,876 | 1,792 |
| 10. | South Carolina | 2,064 | 1,896 | 36. | Minnesota | 1,872 | 1,762 |
| 11. | Mississippi | 2,043 | 1,896 | 37. | Delaware | 1,869 | 1,785 |
| 12. | New Jersey | 2,037 | 1,881 | 38. | Tennessee | 1,859 | 1,778 |
| 13. | New Hampshire | 2,036 | 1,847 | 39. | Texas | 1,856 | 1,788 |
| 14. | Maine | 2,020 | 1,832 | 40. | Washington | 1,854 | 1,758 |
| 15. | Maryland | 1,998 | 1,831 | 41. | Oklahoma | 1,851 | 1,779 |
| 16. | Wisconsin | 1,997 | 1,821 | 42. | North Dakota | 1,847 | 1,745 |
| 17. | Vermont | 1,992 | 1,805 | 43. | Indiana | 1,840 | 1,758 |
| 18. | Georgia | 1,982 | 1,843 | 44. | Nevada | 1,838 | 1,779 |
| 19. | South Dakota | 1,978 | 1,808 | 45. | Montana | 1,828 | 1,741 |
| 20. | North Carolina | 1,973 | 1,832 | 46. | Michigan | 1,827 | 1,759 |
| 21. | California | 1,972 | 1,848 | 47. | Idaho | 1,812 | 1,726 |
| 22. | Arizona | 1,936 | 1,795 | 48. | Kansas | 1,806 | 1,751 |
| 23. | Louisiana | 1,935 | 1,836 | 49. | Utah | 1,790 | 1,727 |
| 24. | Ohio | 1,930 | 1,807 | 50. | Wyoming | 1,766 | 1,729 |
| 25. | Virginia | 1,929 | 1,812 | 51. | Kentucky | 1,756 | 1,723 |
| 26. | Oregon | 1,917 | 1,780 | | | | |

**Note:**

The total cost per case is the sum of the cost per case of medical costs, quality of life losses (including lost productivity), and lost life expectancy. Quality of life and lost life expectancy losses are estimated using revealed preference values for risk avoidance.

Table A7

## MEDICAL COSTS PER CASE OF FOODBORNE ILLNESS

| Rank | State | Cost per Case ($) |
|---|---|---|
| | **The United States** | **112** |
| 1. | New Jersey | 162 |
| 2. | Hawaii | 152 |
| 3. | California | 150 |
| 4. | Florida | 147 |
| 5. | Nevada | 139 |
| 6. | District of Columbia | 138 |
| 7. | Pennsylvania | 134 |
| 8. | Illinois | 130 |
| 9. | Arizona | 126 |
| 10. | Missouri | 125 |
| 11. | Alaska | 123 |
| 12. | New York | 122 |
| 13. | Connecticut | 122 |
| 14. | Texas | 120 |
| 15. | Louisiana | 120 |
| 16. | South Carolina | 120 |
| 17. | Ohio | 118 |
| 18. | Colorado | 117 |
| 19. | Massachusetts | 116 |
| 20. | Michigan | 114 |
| 21. | Mississippi | 113 |
| 22. | Rhode Island | 113 |
| 23. | New Mexico | 111 |
| 24. | Alabama | 110 |
| 25. | Georgia | 108 |
| 26. | Virginia | 106 |
| 27. | Delaware | 106 |
| 28. | New Hampshire | 105 |
| 29. | Kansas | 104 |
| 30. | Oklahoma | 104 |
| 31. | Tennessee | 103 |
| 32. | Wisconsin | 101 |
| 33. | Maine | 101 |
| 34. | Arkansas | 100 |
| 35. | Minnesota | 100 |
| 36. | Indiana | 97 |
| 37. | Nebraska | 97 |
| 38. | North Carolina | 97 |
| 39. | Kentucky | 97 |
| 40. | Oregon | 96 |
| 41. | Washington | 96 |
| 42. | Wyoming | 96 |
| 43. | Utah | 96 |
| 44. | Vermont | 89 |
| 45. | West Virginia | 87 |
| 46. | Iowa | 87 |
| 47. | South Dakota | 84 |
| 48. | Maryland | 82 |
| 49. | Idaho | 81 |
| 50. | North Dakota | 81 |
| 51. | Montana | 78 |

**Note:**

Medical cost losses are based on state-specific costs for hospitalization, drugs, and physician visits.

Table A8

## MEDICAL COST PER CASE BY FOOD SOURCE OF CONTAMINATION

| Rank | State | Cost per Case ($) Produce | Cost per Case ($) Other |
|---|---|---|---|
| | **The United States** | **128** | **107** |
| 1. | New Jersey | 175 | 159 |
| 2. | Hawaii | 166 | 147 |
| 3. | California | 160 | 147 |
| 4. | Florida | 156 | 144 |
| 5. | District of Columbia | 148 | 135 |
| 6. | Pennsylvania | 146 | 131 |
| 7. | Nevada | 146 | 137 |
| 8. | Illinois | 136 | 127 |
| 9. | Arizona | 135 | 123 |
| 10. | New York | 132 | 119 |
| 11. | Connecticut | 132 | 118 |
| 12. | Missouri | 131 | 123 |
| 13. | Alaska | 129 | 121 |
| 14. | South Carolina | 128 | 118 |
| 15. | Louisiana | 126 | 118 |
| 16. | Texas | 126 | 119 |
| 17. | Ohio | 125 | 115 |
| 18. | Massachusetts | 124 | 113 |
| 19. | Colorado | 124 | 115 |
| 20. | Rhode Island | 122 | 110 |
| 21. | Michigan | 120 | 113 |
| 22. | Mississippi | 120 | 111 |
| 23. | New Mexico | 116 | 109 |
| 24. | Alabama | 116 | 108 |
| 25. | New Hampshire | 114 | 103 |
| 26. | Georgia | 114 | 106 |
| 27. | Virginia | 112 | 104 |
| 28. | Delaware | 111 | 104 |
| 29. | Arkansas | 110 | 96 |
| 30. | Maine | 109 | 99 |
| 31. | Oklahoma | 109 | 103 |
| 32. | Wisconsin | 109 | 99 |
| 33. | Kansas | 109 | 103 |
| 34. | Tennessee | 109 | 102 |
| 35. | Minnesota | 105 | 98 |
| 36. | Nebraska | 104 | 95 |
| 37. | Oregon | 103 | 94 |
| 38. | North Carolina | 103 | 95 |
| 39. | Indiana | 102 | 96 |
| 40. | Washington | 102 | 94 |
| 41. | Kentucky | 100 | 96 |
| 42. | Utah | 100 | 95 |
| 43. | Wyoming | 99 | 95 |
| 44. | Vermont | 95 | 87 |
| 45. | Iowa | 93 | 85 |
| 46. | West Virginia | 92 | 86 |
| 47. | South Dakota | 90 | 83 |
| 48. | Maryland | 87 | 80 |
| 49. | North Dakota | 86 | 80 |
| 50. | Idaho | 86 | 80 |
| 51. | Montana | 82 | 77 |

Note:

Medical cost losses are based on state-specific costs for hospitalization, drugs, and physician visits.

Table A9

## COST PER CAPITA OF FOODBORNE ILLNESS

| State | Population | Cost ($ million) | Cost per Capita ($) |
|---|---|---|---|
| **The United States** | **301,621,157** | **152369** | **505** |
| Alabama | 4,627,851 | 2,321 | 502 |
| Alaska | 683,478 | 336 | 492 |
| Arizona | 6,338,755 | 2,943 | 464 |
| Arkansas | 2,834,797 | 1,484 | 523 |
| California | 36,553,215 | 18,613 | 509 |
| Colorado | 4,861,515 | 2,336 | 481 |
| Connecticut | 3,502,309 | 1,893 | 541 |
| D.C. | 588,292 | 314 | 534 |
| Delaware | 864,764 | 418 | 483 |
| Florida | 18,251,243 | 9,799 | 537 |
| Georgia | 9,544,750 | 4,721 | 495 |
| Hawaii | 1,283,388 | 710 | 553 |
| Idaho | 1,499,402 | 682 | 455 |
| Ilinois | 12,852,548 | 6,487 | 505 |
| Indiana | 6,345,289 | 3,069 | 484 |
| Iowa | 2,988,046 | 1,491 | 499 |
| Kansas | 2,775,997 | 1,343 | 484 |
| Kentucky | 4,241,474 | 1,990 | 469 |
| Louisiana | 4,293,204 | 2,314 | 539 |
| Maine | 1,317,207 | 683 | 518 |
| Maryland | 5,618,344 | 2,884 | 513 |
| Massachusetts | 6,449,755 | 3,474 | 539 |
| Michigan | 10,071,822 | 4,958 | 492 |
| Minnesota | 5,197,621 | 2,546 | 490 |
| Mississippi | 2,918,785 | 1,586 | 543 |
| Missouri | 5,878,415 | 2,909 | 495 |
| Montana | 957,861 | 457 | 477 |
| Nebraska | 1,774,571 | 881 | 496 |
| Nevada | 2,565,382 | 1,154 | 450 |
| New Hampshire | 1,315,828 | 681 | 517 |
| New Jersey | 8,685,920 | 4,595 | 529 |
| New Mexico | 1,969,915 | 963 | 489 |
| New York | 19,297,729 | 10,375 | 538 |
| North Carolina | 9,061,032 | 4,487 | 495 |
| North Dakota | 639,715 | 312 | 488 |
| Ohio | 11,466,917 | 5,843 | 510 |
| Oklahoma | 3,617,316 | 1,767 | 489 |
| Oregon | 3,747,455 | 1,817 | 485 |
| Pennsylvania | 12,432,792 | 6,716 | 540 |
| Rhode Island | 1,057,832 | 571 | 540 |
| South Carolina | 4,407,709 | 2,302 | 522 |
| South Dakota | 796,214 | 405 | 509 |
| Tennessee | 6,156,719 | 2,965 | 482 |
| Texas | 23,904,380 | 11,317 | 473 |
| Utah | 2,645,330 | 1,185 | 448 |
| Vermont | 621,254 | 321 | 517 |
| Virginia | 7,712,091 | 3,835 | 497 |
| Washington | 6,468,424 | 3,069 | 474 |
| West Virginia | 1,812,035 | 907 | 501 |
| Wisconsin | 5,601,640 | 2,892 | 516 |
| Wyoming | 522,830 | 245 | 468 |

## APPENDIX B: Methodology Used to Estimate Costs

### Total Health-Related Cost from Foodborne Illness

The health-related cost of foodborne illness for the United States is calculated in a bottom-up manner. First, for each state (s), the total cost of an illness caused by a particular pathogen (p) is estimated to be the product of the number of cases attributed to that pathogen in that state ($Cases_{ps}$) and the cost per illness from that pathogen in that state ($Cost_{ps}$). Next, for a given state, the cost of illness is summed across all 28 pathogen categories examined (including the category of unknown pathogens). Finally, the cost is summed across the 50 states and the District of Columbia to estimate a total cost of foodborne illness for the United States. Mathematically, this is calculated as follows:

$$\text{Health Related Cost} = \sum_{s=1}^{51} \sum_{p=1}^{28} Cases_{ps} \times Cost_{ps}$$

### Cases

The number of cases of pathogen p in a given state is estimated in two ways, depending on availability of data.

A number of foodborne pathogens are classified as notifiable diseases. Where the CDC has collected data on the pathogen through its National Notifiable Diseases Surveillance System (NNDSS) [13], I use the CDC number ($CDC_{ps}$) modified by an underreporting factor ($UR_p$) and adjusted to reflect the fact that not all illnesses from specified pathogens are due to infection through a foodborne vector ($\%Foodborne_p$) [1]. Illnesses are required to be reported to the CDC if they are caused by *Brucella, E. coli, Listeria, Salmonella, Shigella, Cryptosporidium, Cyclospora, Giardia,* and Hepatitis A. The number of illnesses from these pathogens are calculated as:

$$Cases_{ps} = CDC_{ps} \times UR_p \times \%Foodborne_p$$

The number of illnesses caused by other pathogens is the product of the number of illnesses estimated by Mead et. al. (1999) ($Mead_i$), adjusted to account for the proportion of the U.S. population in the state in question (State_Adj) and updated to account for the increase in the U.S. population since 1997 (Pop_Adj) [1, 14].

$$Cases_{ps} = Mead_p \times State\_Adj_s \times Pop\_Adj$$

The total number of cases of foodborne illness estimated to have occurred in 2009 is 81.9 million. More current CDC estimates of the number of cases of foodborne illness in the United States are expected to be released shortly. When this occurs, the numbers in this analysis will have to be updated to reflect the most up-to-date estimates.

### Cost

Estimation of the cost of foodborne illness is more involved. $Cost_{ps}$ is estimated to be the sum of medical costs (doctor visits, lab costs, drugs, and hospitalization) and losses to quality of life (lost life expectancy, lost utility from pain and suffering, and lost productivity from missing work due to illness) [7].

$$Cost_{ps} = Medical_{ps} + Lost\_Quality_{ps}$$

### Sequelae

Adding to the complexity of the model is the fact that many pathogens result in both acute diarrheal illnesses and sequelae that manifest themselves as chronic or acute conditions distinct from the original diarrheal illness. Where identified, the cost of these sequelae are estimated and categorized based on type of cost and are included in the cost per case figures for the pathogens they are associated with. Costs are estimated for sequelae from *Campylobacter* (Guillain-Barré syndrome, reactive arthritis (RA)), *E. coli* (hemolytic uremic syndrome with or without end-stage renal disease), *Listeria* (harm to newborns from infected mothers), *Salmonella* (RA), *Shigella* (RA), and *Yersinia* (RA). Costs from Guillain-Barré syndrome are a function of the probability of having the sequelae, hospital costs, physician costs, and disability losses updated to reflect current medical costs [15-18]. Costs from hemolytic uremic syndrome (HUS) are based on the Frenzen et. al. (2005) economic cost study of HUS and include medical costs, the cost of premature mortality and productivity losses [18, 19]. Costs of sequelae from infection with *Listeria* are drawn from the Buzby et al. (1996) study (updated to reflect current costs) and includes the cost of disabilities in newborns and the productivity losses for their parents [12, 18]. Both Guillain-Barré and *Listeria* costs are underestimates of the true costs because they do not include pain and suffering costs. Finally, reactive arthritis costs are estimated to be the sum of medical costs and monetized QALY losses (productivity losses in the USDA model) [17]. QALY losses are based on duration of illness and proportion of days in which symptoms are present [17, 20]. The costs assessed may be a lower bound estimate because duration is capped at six months due to a paucity of research on the long-term effects of reactive arthritis.

As Table C1 demonstrates, costs resulting from sequelae constitute a significant portion of costs associated with a number of pathogens and represent a nontrivial portion of the overall cost of foodborne illness.

Table C1

**COST OF CHRONIC SEQUELAE[a]**

| Pathogen<br>Sequelae | Cost Per Case ($) | % of Total Cost for Pathogen | Total Social Cost ($ million) |
|---|---|---|---|
| ***Campylobacter*** | | | |
| Guillain-Barré | 2,165 | 24.3 | 4,573 |
| Reactive Arthritis[b] | 3,742 | 42.0 | 7,904 |
| ***E. coli*** | | | |
| Hemolytic Uremic Syndrome | 6,224 | 41.9 | 627 |
| ***Listeria*** | 41,440 | 2.4 | 111 |
| Harm to Newborns | | | |
| ***Salmonella*** | | | 5,403 |
| Reactive Arthritis[b] | 3,742 | 40.9 | |
| ***Shigella*** | | | 361 |
| Reactive Arthritis[b] | 3,742 | 52.8 | |
| ***Yersinia*** | | | 349 |
| Reactive Arthritis[b] | 3,742 | 51.8 | |
| **Total Cost (all pathogens)** | | **12.7** | **19,328** |

[a] Estimates based on estimates using QALY losses.
[b] Reactive arthritis values are very conservative. They do not include arthritis symptoms that persist more than 25 weeks past the resolution of the acute foodborne illness because reliable data on these chronic conditions are lacking.

### Medical Costs

Medical Costs for physician services, pharmaceuticals and hospital costs are calculated separately.

$$\text{Medical}_{ps} = \text{Physician}_{ps} + \text{Pharma}_{p} + \text{Hospital}_{ps}$$

Physician services include the cost of both outpatient and inpatient costs for physician services, as well as the cost of lab work to analyze stool samples (when such samples are collected from) [7, 21-23]. Physician costs are modified for each state by a cost of practice index (developed by Medicare to allow doctors in different areas to charge rates based on local market conditions) [22]. Between 12.7% and 92.2% of persons afflicted with an illness see a physician, depending on the pathogen implicated in the illness [1, 7, 21].

Pharmaceutical costs are not state-specific, but are differentiated based on whether the person with an illness saw a physician or was hospitalized [7, 18, 24, 25].

Hospital costs are determined based on the average charges reported by hospitals for admissions with relevant ICD-9 condition codes (as reported in AHRQ's Healthcare Cost & Utilization Project database) [26]. These costs do not include physician services in hospitals. Hospitalization rates are taken from Mead et al. (1999)[1]. Costs are modified to account for state differences in hospitalization costs [27].

### Lost Quality of Life

Different methods of estimating quality of life losses due to injury and illness have been developed. Two methods representing the approaches of the U.S. Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA) are presented for comparison. The USDA approach is more conservative and, by their own admission, does not account for pain and suffering losses attributable to illnesses [12].

Both the USDA and the FDA employ a measure to account for losses due to reduced life expectancy. The value of statistical life (VSL) measure used by both is based on hedonic wage studies that suggest workers must be paid a premium to engage in work associated with a higher risk of death. A meta-analysis of a number of such studies in 2003 yielded an average VSL of $6.7 million [11]. Updated to account for inflation, the value in 2009 is $7.9 million [18]. This value is applied to deaths resulting from foodborne illness. State differences in VSL measures are not available at this point.

#### *The USDA Approach*

To account for other quality of life losses, the USDA measures productivity losses based on the number of days of work lost due to illness and the forgone compensation resulting from such absences. This study improves on the USDA approach by adjusting for state differences in employment cost and employment rates [7, 28]. Additionally, when children are ill, caregivers who work are also assumed to have productivity losses. Approximately 58% of families will have one parent take off work to be a caregiver when their child is ill [29]. The inclusion of productivity losses due to illnesses affecting children leads to an increase in the productivity loss estimate by almost 50%.

The USDA-inspired formula for lost quality of life is:

$$\text{Lost\_Quality}_{ps} = \text{VSL}_{p} + \text{Prod\_Loss}_{ps}$$

#### *The FDA Approach*

The FDA approach employs a more inclusive quality of life loss measure. FDA starts with quality adjusted life year (QALY) measures that are widely used in cost –effectiveness research. For example, using state-of-the-art EQ-5D measures for QALY losses suggests that an individual with a case of foodborne illness that does not require hospitalization will experience utility losses of 47.3% over the period that person is ill [7]. This measure accounts for pain, suffering, and functional disability. The discounted value of a day lost (VSLD) can easily be derived from VSL numbers and is estimated to be $956 [11, 18]. This means that a mild illness that lasts for one day will result in $452 in utility losses. Productivity losses are not included in this approach since functional disability is already accounted for.

In sum, the FDA approach can be illustrated as:

$$\text{Lost\_Quality}_{ps} = \text{VSL}_p + \text{QUALD}_p \times \text{VSLD}$$

As the above equation suggests, the QALY approach does not allow for state differences in lost quality of life.

### Produce-Related Costs from Foodborne Illness

The burden of foodborne illness for produce is also presented above. If the percent of pathogen p and state s pathogens attributable to produce is $\text{Prod\%}_{ps}$, the total number of foodborne illnesses associated with produce is:

$$\text{Produce Illnesses} = \sum_{s=1}^{51} \sum_{p=1}^{28} \text{Cases}_{ps} \times \text{Prod\%}_p$$

$\text{Prod\%}_p$ is based on 2003-2007 data from the CDC's Foodborne Disease Outbreak Surveillance System [2]. First, outbreaks with no associated food product are dropped. Next, outbreaks with a produce product (fresh, canned, or processed) are identified and illnesses are divided evenly between each of the listed food vehicles. The number of illnesses attributable to produce products was estimated separately for nine specific pathogens and four pathogen categories. For each category, this number is divided by the total number of illnesses attributable to outbreaks in that category, yielding $\text{Prod\%}_p$. Too few outbreaks were identified to reliably estimate state-specific values for the proportion of illnesses attributable to produce.

The total cost of produce-related illnesses is simply the product of the number of produce illnesses and the cost per case, summed across states and pathogens.

$$\text{Produce Related Cost} = \sum_{s=1}^{51} \sum_{p=1}^{28} \text{Cases}_{ps} \times \text{Prod\%}_p \times \text{Cost}_{ps}$$

Although I assume that pathogen-specific costs associated with each case of foodborne illness do not vary by food type, the average cost per case of foodborne illness will be affected by any change in the distribution of illnesses across pathogen type.

### Acknowledgements

The Produce Safety Project commissioned the writing of this report and is responsible for its content. PSP would like to acknowledge and thank for their reviews of this report: Frank Ackerman, Global Development and Environment Institute, Tufts University, and Richard Williams, Managing Director, Regulatory Studies Program and Government Accountability Project, Mercatus Center at George Mason University. The views in this report do not necessarily reflect the views of the reviewers or of The Pew Charitable Trusts.

1. Mead, P.S., et al., *Food-Related Illness and Death in the United States.* Emerging Infectious Diseases, 1999. 5(5): p. 607-625.
2. Centers for Disease Control and Prevention. *Outbreak Surveillance Data.* 2009 [cited May 5, 2009]; Available from: http://www.cdc.gov/foodborneoutbreaks/outbreak_data.htm.
3. Centers for Disease Control and Prevention. *FoodNet Reports.* 2009 [cited May 5, 2009]; Available from: http://www.cdc.gov/FoodNet/reports.htm.
4. Buzby, J.C. and T. Roberts, *The Economics of Enteric Infections: Human Foodborne Disease Costs.* Gastroenterology, 2009. 136: p. 1851-1862.
5. Roberts, T., et al., *The Long-Term Health Outcomes of Selected Foodborne Pathogens.* 2009, Center for Foodborne Illness Research and Prevention. p. 28.
6. General Accounting Office, *Food Safety: Overview of Federal and State Expenditures.* 2001.
7. Scharff, R.L., J. McDowell, and L. Medeiros, *The Economic Cost of Foodborne Illness in Ohio.* Journal of Food Protection, 2009. 72(1): p. 128-136.
8. Fox, J.A., et al., *Experimental auctions to measure willingness to pay for food safety, in Valuing Food Safety and Nutrition,* J.A. Caswell, Editor. 1995, Westview Press: Boulder.
9. Hammitt, J.K. and K. Haninger, *Willingness to Pay for Food Safety: Sensitivity to Duration and Severity of Illness.* American Journal of Agricultural Economics, 2007. 89(5): p. 1170-1175.
10. Roberts, T., *WTP Estimates of the Societal Costs of U.S. Food-Borne Illness.* American Journal of Agricultural Economics, 2007. 89(5): p. 1183-1188.
11. Viscusi, W.K. and J.E. Aldy, *The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World.* Journal of Risk and Uncertainty, 2004. 27(1): p. 5-76.
12. Buzby, J.C., et al., *Bacterial Foodborne Disease: Medical Costs and Productivity Losses*, U. S. Department of Agriculture, Editor. 1996, Economic Research Service. p. 100.
13. Centers for Disease Control and Prevention, *National Notifiable Diseases Surveillance System.* 2009.
14. Census Bureau, *Statistical Abstract of the United States: 2009* 2009.
15. Allos, B.M. and M.J. Blaser, *Campylobacter jejuni and the expanding spectrum of related infections.* Clinical Infectious Diseases, 1995. 20: p. 1092-1099.
16. Frenzen, P., *Economic cost of Guillain-Barré syndrome in the United States.* Neurology, 2008. 71(1): p. 21-27.
17. Havelaar, A.H., *Health Burden in the Netherlands due to infection with thermophilic Campylobacter spp.* Epidemiology and Infection, 2000. 125(3): p. 505-522.
18. Bureau of Labor Statistics, *Consumer Price Index - All Urban Consumers.* 2009.
19. Frenzen, P.D., A. Drake, and F.J. Angulo, *Economic Cost of Illness Due to Escherichia coli O 157 Infections in the United States.* Journal of Food Protection, 2005. 68(12): p. 2623-2630.
20. Townes, J.M., et al., *Reactive arthritis following culture-confirmed infections with bacterial enteric pathogens in Minnesota and Oregon: a population-based study.* Annals of the Rheumatic Diseases, 2008. 67(12): p. 1689-1696.
21. Hawkins, M., et al., *The Burden of Diarrheal Illness in FoodNet, 2000-2001,* in Conference on Emerging Infectious Diseases. 2002: Atlanta, GA.
22. Practice Management Information Corporation, *Medical Fees in the United States.* 2009, Los Angeles: PMIC.
23. American Medical Association, *Outpatient Services CPT.* 2007, Chicago, IL: American Medical Association.
24. Cohen, M.L., et al., *An Assessment of Patient-Related Economic Costs in an Outbreak of Salmonellosis.* New England Journal of Medicine, 1978. 299(9): p. 459-460.
25. Frenzen, P., *Foodborne Illness Cost Calculator: STEC O157.* 2007, Economic Research Service.
26. Agency for Healthcare Research and Quality, *Healthcare Cost and Utilization Project.* 2009.
27. Hay, J., *Hospital Cost Drivers: An Evaluation of State-Level Data.* 2002, University of Southern California: Los Angeles. p. 41.
28. Bureau of Labor Statistics, *Employer Costs for Employee Compensation.* 2009.
29. Department of Health and Human Services. *Family, Work and Child Care.* 2002 [cited 2009; Available from: http://aspe.hhs.gov/hsp/connections-charts04/ch3.htm

PRODUCE SAFETY PROJECT ISSUE BRIEF:

# FARM WORKER HEALTH AND HYGIENE

Robert B. Gravani, Ph.D., Department of Food Science, Cornell University

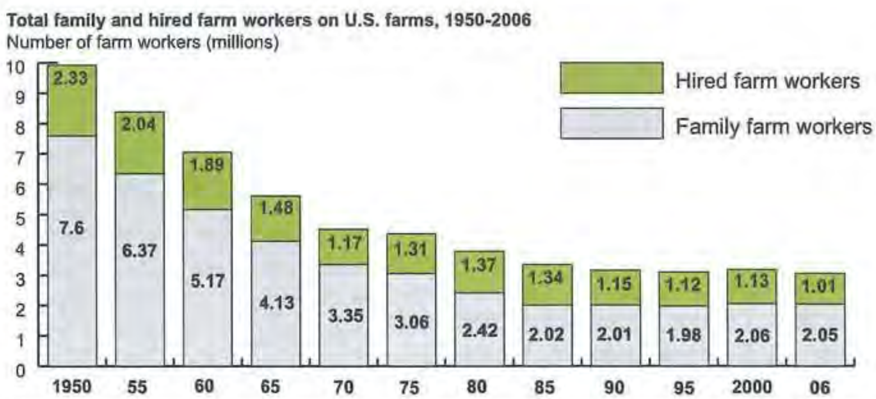
PRODUCE SAFETY PROJECT

## Introduction

In the United States, the abundant and affordable supply of fresh fruits and vegetables we enjoy is due in large part to the critical role that farm workers play in the planting, cultivating, harvesting, packing and processing of these important foods. Farm workers have been a vital part of agriculture for centuries especially in the production of labor intensive crops. As farming became a large-scale industry in California in the 1860s, Native Americans and later Chinese immigrants were recruited to work on farms to meet the growing demand for fruit. Later, workers from Japan, Pakistan, India, the Philippines and Mexico were recruited for agricultural activities (Kandel, 2008a). Since then, farm workers have played a crucial role in the history of agricultural development in the U.S.

In the last century hired farm workers have declined from ~3.4 million to just over a million in 2006 and currently make up less than 1% of all U.S. workers (ERS, USDA, 2008). Advances in technological innovation, changing production methods and mechanization have brought about increased productivity while reducing the agricultural labor force and the number of hired farm workers within it (Kandel, 2008a). It is estimated that the more than 1.01 million hired farm workers employed in U.S. agriculture (Kandel, 2008b) make up a third of the estimated three million people employed in the agricultural labor force. The other 2.05 million people include self-employed farmers and their unpaid family members (Kandel, 2008a). A profile of hired and family farm workers on U.S. farms from 1950 to 2006 is shown in Figure 1 (Kandel, 2008a). While there has been a steady decline of hired farm workers, family farm workers have decreased by over 5.5 million people. According to the National Agricultural Workers Survey, between 1989 and 2006, children under age 18 made up 5.5% of the hired crop farm worker labor force (Kandel, 2008a). In the past decade, an increasing U.S. population, a growing demand for year-round fresh fruits and vegetables, and a farm sector that is consolidating have stabilized the demand for farm labor. However, non-farm employment opportunities for farmers have increased their reliance on hired farm workers as agricultural production is now concentrated on fewer, larger farms.

**Figure 1. A profile of farm workers on U.S. farms from 1950 to 2006 ***




Notes: Family farm workers include self-employed farmers and unpaid family members. Hired farm workers include direct hires and agricultural service workers who are often hired through labor contractors. The 2006 family farm workers figure of 2.05 million is estimated from a simple linear extrapolation form the last available annual figures for self-employed and nonpaid family farm workers collected by NASS from 2000 to 2002.
**Source:** Farm Labor Survey, National Agricultural Statistics Service, USDA.

## Demographic Characteristics of Farm Workers

Since farm labor is physically demanding, hired farm workers are usually younger, less educated, white, Hispanic, male, married and more likely to be foreign born. The term "Hispanic" encompasses people whose origins include Mexico, Central America, South America and the Caribbean. People of Hispanic origin may be of any race. Selected demographic characteristics of hired farm workers are shown in Table 1 (Kandel, 2008a; Kandel, 2008b, Kandel, 2008c).

Some important information to be noted in Table 1 is that almost 81% of hired farm workers are male, nearly three quarters of them are less than 44 years of age (median age of 34 years), 50% have not graduated from high school and over half are married. More than a third of farm workers had children under 18 years of age in their households.

Table 1. Demographic Characteristics of hired farm workers in 2006 *

| Category | Precent |
|---|---|
| ***Gender*** | |
| Male | 80.9 |
| Female | 19.1 |
| ***Age Distribution*** | |
| Under age 21 | 15.1 |
| Between ages 21-44 | 56.4 |
| Over age 44 | 28.1 |
| **Median age = 34 years** | |
| ***Race*** | |
| White | 91.7 |
| Black | 4.0 |
| Native American | 1.4 |
| Asian | 2.9 |
| **Hispanic ethnicity** | 43.0 |
| ***Country of Birth*** | |
| Mexico | 37.3 |
| U.S. | 57.8 |
| All other countries | 4.9 |
| ***Education*** | |
| Less than 9th grade | 30.0 |
| Grades 9-12, no diploma | 21.1 |
| High school graduate | 28.2 |
| Some college | 20.7 |
| ***Marital Status*** | |
| Married | 52.7 |
| Div./wid./sep. | 9.1 |
| Never Married | 38.1 |
| Children under 18 in household | 35.8 |

**Adapted from ERS analysis of Annual Averages from 2006 Current Population Survey Earnings File Data. In Kandel, W. 2008. Profile of Hired Farm Workers, A 2008 Update. Economic Research Report No. 60. ERS, USDA, July, 2008*

## Migration of Farm Labor

The popular perception of hired farm workers, who provide labor for fruit and vegetable operations, is that they are follow-the-crop migrants, but this group actually comprises less than 12% of the crop farm work force. They travel to multiple work locations in consistent geographic patterns that vary with the agricultural season requirements (Kandel,, 2008a; Kandel, 2008b). Migrant workers are permanently settling in places where they previously worked temporarily and perform multiple tasks on the same farm or hold other local jobs throughout the year (Kandel, 2008b). Since the mid-1990s, the increasing use of year-round production techniques, as well as a greater enforcement of border regulations, have increased the proportion of settled farm workers, now more that 50% of hired farm workers in the U.S. Another major category of hired farm workers is those who travel between a single work location and their U.S. or foreign homes and are known as "shuttler" migrants. They currently make up about 20% of hired farm labor. The last category of hired farm workers are considered "newcomers" who are foreign-born and have lived in the U.S. less than a year. This group, whose work patterns were not determined during worker surveys, comprise ~15% of hired farm workers (Kandel, 2008a).

According to information from the 2006 Current Population Survey (CPS), approximately 25% of all hired crop farm workers live in the Southwest, while 12% live in the South, 8% in the Midwest, 7% in the West and 3% in the Northeast. Almost half of all hired farm workers live in five states: California, Texas, North Carolina, Washington and Oregon (Kandel, 2008a).

## Health Status of Farm Workers

Although research on the health status of hired farm workers is increasing, the overall health of this population is not well understood (Villarejo, 2003). Their economic status, lack of health insurance, as well as cultural and language barriers, prevent large numbers of these workers from obtaining the health care services that they need. Reports in the literature confirm a higher than average prevalence of several infectious diseases among these workers including parasitic infections and tuberculosis (Villarejo, 2003). Most farm workers access health care services only when it is absolutely essential and then visit hospital emergency rooms or community clinics.

## Fruit and Vegetable Production

Today, U.S. consumers have a wide variety of fresh fruits and vegetables to choose from with over 345 different produce items that come from over 130 countries around the world, many of them being available year-round (Rangarajan, et al. 1999). Since 1970, per capita consumption of fresh vegetables increased from 154 pounds to 202 pounds in 2007, while fresh fruit consumption during the same time period increased from 101 pounds to 126 pounds. According to the U.S.D.A., in 2007 the overall per capita availability of fresh fruits and vegetables in the U.S. was 328 pounds per person (ERS, USDA, 2009). As the per capita consumption of fresh fruits and vegetables was increasing, epidemiologists at the Centers for Disease Control and Prevention noticed another trend developing. From the early 1970s to the present, the number of foodborne outbreaks associated with fresh produce increased steadily and more than doubled, along with the number of people affected also doubling (Gravani, 2009). Bacteria, viruses and parasites were identified as causative agents and a wide variety of fresh fruits and vegetables were associated with these outbreaks. Since many fruits and vegetables are often eaten raw, they never receive heat treatments to kill pathogenic organisms that may be present. According to statistics compiled by the U.S. Food and Drug Administration (FDA), Center for Food Safety and Applied Nutrition (CFSAN), there were 82 produce-associated outbreaks from 1996 through 2008, associated with more than 20 commodities (Vierk, et. al.; 2008, Vierk, 2009).

## Produce Contamination by Workers

Fresh produce can become contaminated from contact with soil; manure; improperly composted manure; irrigation water; fecal material from wild and domestic animals; farm, packinghouse and terminal market workers; contaminated equipment in the fields, packinghouse and distribution system; wash rinse and flume water; ice; cooling equipment and transportation vehicles; cross-contamination from other foods; and improper storage, packaging, display and preparation (Gravani, 2009; Bihn and Gravani, 2006, FDA, USDA, & CDC, 1998 ). As mentioned, there are numerous ways for produce to be contaminated, but investigations of farms and packing houses that had been incriminated in produce-associated outbreaks, revealed that infected workers and poor worker hygiene were often implicated (Michaels and Todd, 2006).

Farm workers have intimate contact with the fruits and vegetables as they harvest, sort and pack these foods, and so worker health and hygiene becomes a matter of concern, especially for commodities that require extensive manipulation and handling during harvesting, preparation for packing and processing. Pathogenic organisms of human health significance—including *Salmonella* species, *E.coli* O157:H7, *Shigella*, *Cryptosporidium*, *Cyclospora*, Hepatitis A, and Norovirus—associated with infected farm workers, have been implicated in outbreaks involving strawberries, green onions (scallions), raspberries, tomatoes, leaf lettuce, basil, parsley and other produce items (Bihn and Gravani; 2006, Gravani, 2009; Michaels and Todd, 2006). A detailed list of selected produce outbreaks from 1987-2003, associated with infected workers is shown in Table 2 (Michaels and Todd, 2006).

Infected workers who contaminate produce are likely working when they are ill and do not follow proper hygiene steps such as effective hand washing. Transmission of human pathogens can occur via the fecal-oral route either by direct contact with a person who is infected or by ingesting food or water that has been contaminated with the pathogen. Infected farm workers may be asymptomatic, but will shed the organisms in their feces, depending on the agent, from periods as short as a few hours to years and be capable of causing an outbreak (Michaels and Todd, 2006). Some of the factors contributing to outbreaks associated with produce caused by infected workers include lack of adequate water supply, workers with limited hygiene education, poor or no toilet facilities, bare hand contact with produce items, lack of food contact surface sanitation and lack of childcare for workers (Michaels and Todd, 2006).

Strategies for preventing contamination by workers involve well-designed and effectively delivered education and training programs that include information on the importance of good health and hygiene to produce safety, proper use of field and packinghouse toilets, effective hand washing practices and appropriate use of gloves. Even though discussing urination and defecation are difficult topics to address, it is vital that workers understand their role in preventing the contamination of the produce they handle (Bihn and Gravani, 2006). Since many commodities are hand-harvested and packed directly into consumer-ready containers in the field, it is also important for workers to be reminded that they are handling ready-to-eat products and are considered food handlers (Gravani, 2009; Bihn and Gravani, 2006).

Table 2. Produce Outbreaks Associated with Infected Workers*

| Date | Produce | Infectious Agent | Number of Cases | Produce Origin | Reference |
|---|---|---|---|---|---|
| 1987 | Raspberries (frozen) | Hepatitis A Virus | 92 | United Kingdom | Reid and Robinson, 1987 |
| 1989 | Canned mush-rooms | *Staphylococcus aureus* | 99 | China | Levine et al., 1996 |
| 1990 | Strawberries | Hepatitis A Virus | 53 | United States | Niu et al., 1992 |
| 1991 | Frozen coconut milk | *Vibrio Cholera O1* | 3 | Thailand | Taylor et al., 1993 |
| 1994 | Green onions (scallions) | *Shigella flexneri* | 72 | California | Cook et al., 1995 |
| 1996 | Leaf lettuce | *E. coli* O157:H7 | 49 | United States | Hilborn et al., 1999 |
| 1997 | Strawberries (frozen) | Hepatitis A virus | 250 | California | CDC, 1997 |
| 1997 | Green onions (scallions) | *Cryptosporidium parvum* | 55 | United States | CDC, 1998 |
| 1997 | Basil | *Cyclospora cayetanensis* | 341 | United States | Pritchett et al., 1997 |
| 1998 | Green onions (scallions) | Hepatitis A virus | 43 | United States/California | Dentinger et al., 2001 |
| 1998 | Mamey (sapote fruit pulp) | *Salmonella typhi* | 13 | Guatemala | Katz et al., 2002 |
| 1999 | Parsley (chopped) | *Shigella sonnei* | 486 | United States | CDC, 1999 |
| 2003 | Parsley (chopped) | Enterohemorrhagic *E. coli* | 77 | United States | Naimi et al., 2003 |

** From: Michaels, B. and E. Todd. 2006. Farm Worker Personal Hygiene Requirements During Harvesting, Processing and Packaging of Plant Products. In: Microbial Hazard Identification in Fresh Fruits and Vegetables, J. James, Editor. John Wiley & Sons, Inc. pps.115-153.*

## Effective Worker Education and Training Programs

Preventing contamination by workers involves the total commitment and leadership of top management in a produce company. Management needs to believe in the importance of produce safety and in building a culture of food safety within the organization. Management must also provide the necessary resources to achieve these goals and to develop and deliver an effective worker education and training program. Every employee working on the farm and in the packinghouse, including newly hired employees, seasonal or part-time workers, family members, and others need to know the basics of food sanitation and their important role in assuring the safety of the produce that they harvest, sort and pack. They need to understand why good health and hygiene is important and the reasons that they are being asked to follow these rules. They should understand the consequences of poor health and hygiene and how that affects them, their families (especially their children) and friends and the safety of all who consume the fresh fruits and vegetables that they handle. Knowledgeable workers who consistently perform appropriate tasks correctly will reduce microbial risks (Bihn and Gravani, 2006).

Training programs should be practical, meaningful, aimed at the appropriate education level for the workers being trained and delivered by knowledgeable individuals who speak the language of the employees that they are addressing. In a 2002 survey of 450 fruit and vegetable growers in New York State, it was learned that many growers did not have a worker training program related to worker health and hygiene. This survey was conducted before farm safety audits were commonly used to determine compliance with Good Agricultural Practices (GAPs) guidelines. When asked, "Do you offer worker training that specifically addresses the importance of hand washing and personal hygiene?", 57.1% of the respondents said no. When they were asked why they had not implemented such a program and were given a list of eight optional responses, the most frequent response (29.8%) was "the workers are not interested." This response was not supported by a parallel survey of 680 New York State farm workers. When farm workers were asked, "Would you be interested in receiving more information and training on proper hand washing for your own protection and to protect the fruits and vegetables you harvest and pack?", 73.7% of the respondents said yes. Growers were given the option to provide their own response to why they didn't offer training and many did. Some of the responses included comments such as "not needed at my operation," "common sense information," "family workers," "not my job to raise workers," "not a high priority," and "I'm not in the hygiene business." These responses indicated that many growers did not understand the link between produce safety and worker health and hygiene or that they were not concerned with this link (Bihn and Gravani, 2006). Today, with GAPs audits of farm operations being required by produce buyers, there is a section in most audit checklists, including the USDA GAPs and Good Handling Practices (GHPs) Audit Verification Checklist (USDA, 2009) that addresses worker health and hygiene. Growers must conduct worker training programs related to these important issues and document them or risk losing audit points in this audit category.

The National Good Agricultural Practices (GAPs) program in the Department of Food Science at Cornell University has develop some practical education educational materials in English and Spanish that can be used in farm worker produce safety education and training programs (www.gaps.cornell.edu) (Bihn and Gravani, 2006).

### Worker Health and Hygiene

First, workers must recognize that when they are sick, they should, ideally, not report to work, or alternatively, report their illness to a supervisor who can assign them to a job where they will not handle produce. Workers displaying symptoms such as nausea, vomiting, diarrhea, severe abdominal pain, exposed cuts, sores or open wounds, Hepatitis A or yellow jaundiced skin and eyes should not have direct contact with food. In addition, workers with upper respiratory infections should also be assigned duties not involving food handling. Workers who have been removed from contact with produce should only be returned to these jobs when cleared by a licensed health care professional, stating that they are no longer infectious (Michaels and Todd, 2006).

### Personal Cleanliness

Worker hygiene begins with instruction on the importance of personal cleanliness so that workers know how to prepare for their work day and what is expected of them on the job. Important good hygiene habits include tasks such as taking a shower every day, wearing task-appropriate, clean clothes to work, keeping fingernails trimmed short and clean, using only designated toilet facilities at all times (either field toilets, toilets in the packinghouse, or other appropriate facilities), washing hands thoroughly and often, using appropriate head gear, and not eating food or candy, chewing gum or using tobacco products while on the job working with produce (Michaels and Todd, 2006). In addition, instruction on the prompt and proper treatment (first aid) for cuts, abrasions and other injuries, as well as policies and procedures on the specific handling and disposition of produce and food contact surfaces that come in contact with blood and other body fluids are also vital.

### Water

The availability of clean, potable water from a sanitary source for farm workers is needed for consumption and hand washing and reduces the likelihood of enteric organisms contaminating the hands of workers. Drinking water should be provided to ensure that workers do not get dehydrated and ill while working. The water supply should be in good working order and be monitored on a daily basis. Water should be stored in clean and previously sanitized containers and tanks that are cleaned and sanitized daily. The containers should be covered, kept away from sun and excessive heat and single-use, disposable cups should be provided (Michaels and Todd, 2006).

### Jewelry and Personal Adornments

Every produce company should have a policy on the use of jewelry and personal adornments and clearly communicate this information when new workers are hired and to long-time employees during refresher training. Jewelry of all kinds including rings, bracelets, earrings, necklaces, piercings, as well as false finger nails and other personal adornments such as badges, buttons, etc. can create a physical hazard if they should break or become dislodged and fall into the product. These items can also be a personal safety risk to employees who may be working on or near moving equipment. In addition, when working in packaging or processing areas, workers must also be aware that pens, pencils, thermometers, and other small items should not be kept in coat or shirt pockets as they might fall into the product. Rules on the use of jewelry and other adornments should be strictly enforced to prevent physical hazards from entering product. Appropriate head gear should be worn when workers are handling product and facial hair must also be covered (Michaels and Todd, 2006).

## Proper Toilet Use

The proper use of toilet facilities should also be addressed in worker health and hygiene training programs. Many growers have noticed that workers do not always put used toilet paper into the toilet. In the survey of more than 680 farm workers in New York cited above, when asked, "When you use the toilet, where do you put the toilet paper?" 46.6% of the respondents said in the toilet, 44.8% said in a trash can, 1.6% said next to the toilet, 0.9% said on the ground and 6.2% provided their own responses which included "in a bag to throw away later," "in the woods," "I go in the field and leave the paper there," and "I can't answer–there are no toilets." The belief that toilet paper belongs in the garbage likely originates from the fact that many farm workers immigrate from countries where the plumbing systems cannot tolerate the disposition of the toilet paper directly into the toilet. It is common in those countries to dispose of used toilet paper in a can near the toilet and not directly in the toilet. There is a need to clearly communicate how toilets in the U.S. work and clarify the expectations for sanitary practices (Bihn and Gravani, 2006).

It is vital that growers provide clean and sanitary toilets and hand washing facilities that are properly stocked with soap, water and single-use paper towels in the field as well as in packinghouse operations. OSHA field sanitation regulations state that field toilets be within one quarter mile walk of where employees are working and one toilet and one hand washing facitlity is required for each 20 employees (29 CFR 1928.110). Providing these facilities at this distance, or closer (depending on the terrain), to where people are working and enforcing their proper use, will promote good health and hygiene, reinforcing the farm's commitment to produce safety (Bihn and Gravani, 2006).

## Hand Washing

Hand washing is the single most important way to prevent the transmission of infectious diseases and should be practiced by all workers who handle food (Michaels and Todd, 2006).

Although most people think they know how to properly wash their hands, it is important to provide instruction about the correct procedure. Effective hand washing procedure includes the following steps:

1. Allow enough time to wash hands properly.
2. Wet the hands and exposed areas of the arm with warm water
3. Apply an adequate amount of soap to the hands and soap thoroughly
4. Rub lathered hands together for at least 20 seconds (sing "Happy Birthday" twice or the alphabet song once)
5. Pay particular attention to the areas around and underneath the fingernails, palms, the top of the hands, between the fingers, and exposed areas of the wrists and forearms
6. Rinse thoroughly with running water
7. Dry the hands with a single service, disposable paper towel
8. Properly dispose of the used towel into a container designed for this purpose

Hand washing is an activity that should always be done before beginning work and should be repeated frequently throughout the day.

It is especially critical after performing any of the following activities (Bihn and Gravani, 2006; Michaels and Todd, 2006):

- Using the toilet
- Eating foods or drinking beverages
- Returning to work after a break
- Coughing, sneezing or blowing the nose
- Touching or scratching the face, mouth, nose, skin, hair, or ears
- Smoking or using chewing tobacco
- Touching dirty surfaces, equipment or utensils
- Handling dirty raw materials, trash, garbage, or waste
- Handling contaminated or potentially contaminated materials
- Performing maintenance on any equipment
- Touching or handling agricultural chemicals including fertilizers, pesticides, and cleaning materials
- Any other situation that may lead to contamination of the hands

## Gloves

Since bare hand contact with ready to eat foods has often been linked to foodborne illness outbreaks, it is important that workers wear gloves when handling produce. Clean, intact gloves can provide an effective barrier between hands and produce. Sometimes, workers can forget that gloves can become soiled and dirty, just like their hands, and contaminate the produce that they are harvesting, sorting, grading or packing. Disposable gloves should be changed frequently, especially when they are worn for long period of time; get ripped, damaged or soiled; or used for tasks other than product contact. Once disposable gloves are removed, they should be discarded and not reused (Bihn and Gravani, 2006). Reusable gloves should be washed and sanitized frequently and thrown away when they become old, soiled, torn or uncleanable. Gloves are not a substitute for proper hand washing. The proper procedure for glove use is to wash hands thoroughly and then put on clean, intact gloves. For some workers, the use of gloves inhibits their job performance due to lack of tactile sensitivity. In these instances, frequent and proper hand washing followed by the use of a sanitizer hand dip is the best way to reduce microbial risks (Bihn and Gravani, 2006).

It is very clear that people who work on farms and in packinghouses play a key role in assuring the safety of fresh fruits and vegetables that they harvest, sort, and pack. Top management commitment to food safety, a well designed and implemented farm worker education and training program, clear and enforced rules for food safety and sanitation, as well as attention to details, will reduce the risk of produce associated foodborne illnesses linked to workers.

Bihn, E.A. & R.B. Gravani. 2006. Role of Good Agricultural Practices in Fruit and Vegetable Safety. *In Microbiology of Fresh Produce*. Karl R.Matthews (Ed.), ASM Press,Washington, DC. P. 21-53

Food & Drug Administration, United States Department of Agriculture and Centers for Disease Control and Prevention. 1998. Guidance for Industry: Guide to Minimize Food Safety Hazards for Fresh Fruits and Vegetables. Food & Drug Administration, Washington, D.C. 40 pps.

Good Agricultural Practices Network for Education and Training (GAPs Net) www.gaps.cornell.edu.

Gravani, R.B. 2009. The Role of Good Agricultural Practices in Produce Safety. In Microbial Safety of Fresh Produce. X. Fan, B.A. Niemira, C.J. Doona, F.E. Feeherry and R.B. Gravani. Wiley-Blackwell Publishing. Ames, IA. P 101-117

Kandel, William. 2008a. Profile of Hired Farmworkers: A 2008 Update. Economic Research Report, No. 60, Economic Research Service, United States Department of Agriculture, July 2008. 59 pps.

Kandel, William. 2008b. Rural Labor and Education: Farm Labor. Economic Research Service, United States Department of Agriculture, Briefing Rooms. http://www.ers.usda.gov. Briefing Labor and Education/ farm labor.htm. Accessed 11/6/2009

Kandel, William. 2008c. Hired Farmworkers a Major Input for Some U.S. Farm Sectors. Amber Waves, Economic Research Service, U.S. Department of Agriculture. April, 2008. http://www.ers.usda.gov/amberwaves/April08/features/hiredfarm.htm. Accessed 11/6/2009

Michaels, B. and E. Todd. 2006 Food worker Personal Hygiene Requirements during Harvesting, Processing, and Packaging of Plant Products. Microbial Hazard Identification in Fresh Fruit and Vegetables. Jennylynd James, John Wiley & Sons, Inc. NY, NY. p 115-153

Rangarajan, A., E.A. Bihn, R.B. Gravani, D.L. Scott and M.P. Pritts. 1999 Food Safety Begins on The Farm. A growers Guide. National GAPs Program, Department of Food Science, Cornell University, Ithaca, NY. 28 pps

U.S. Department of Agriculture, Agricultural Marketing Service. 2009. Good Agricultural Practices and Good Handling Practices Audit Verification Checklist. http://www.AMS.USDA.gov/AMSv1.0/getfiledDocName=STELPRDC5050869. Accessed 2/10/2010

U.S. Department of Labor. 2005. Occupational Safety and Health Administration. Occupational Safety and Health Standards for Agriculture. Code of Federal Regulations, Title 29, Part 192.110. Field Sanitation.

Vierk, K., E. Elliot, T. Gondwe, J. Guzewich, T. Hill, K. Klontz, P. McCarthy, S. McGarry, M. Ross, J. Sanders, D. Street and B. Timbo. 2008. Outbreaks Associated with FDA/CFSAN-regulated Foods: 1996-2007. Center for Food Safety and Applied Nutrition, U.S. Food and Drug Administration, College Park, MD. PDF File, 27 Slides.

Vierk, K. 2009 Center for Food Safety and Applied Nutrition, U.S. Food and Drug Administration, Personal Communication.

Villarejo, D. 2003. The Health of U.S. Hired Farm Workers, Annual Review of Public Health, 24:175–193.

**The Produce Safety Project commissioned this report and is responsible for its content.**
**The views expressed in the paper do not necessarily reflect those of The Pew Charitable Trusts.**

SAFE AND SUSTAINABLE:

# CO-MANAGING FOR FOOD SAFETY AND ECOLOGICAL HEALTH IN CALIFORNIA'S CENTRAL COAST REGION

February 17, 2010

## Table of Contents




**Lowell, K., J. Langholz,** and D. Stuart. 2010. Safe and Sustainable: Co-Managing for Food Safety and Ecological Health in California's Central Coast Region. San Francisco, CA. and Washington, D.C: The Nature Conservancy of California and the Georgetown University Produce Safety Project.

## Acknowledgements

A diverse group of organizations and individuals helped develop this report. **The acknowledgments of individual persons listed below, and the organizations that these individuals are currently affiliated with, does not imply endorsement nor approval of this document in its entirety or in part by these individual persons or the organizations listed.**

We are especially grateful to members of the Food Safety and Conservation Co-Management Technical Advisory Committee and the Science Advisory Panel, some of whom are listed below.

***Food Safety and Conservation Co-Management Advisory Committee:***

Rob Atwill, Interim Director, Western Institute for Food Safety and Security
Jo Ann Baumgartner, Executive Director, Wild Farm Alliance
Jim Bogart, President, Grower-Shipper Association of Central California
Steve Dorrance, Owner/Manager, Dorrance Ranches, LP
Hank Giclas, VP Strategic Planning, Science and Tech., Western Growers' Association
Jeffery Gilles, Principal and Managing Partner, Lombardo & Gilles, LLP
Bill Gillette, Agricultural Commissioner, Santa Barbara County
Eric Holst, Managing Dir., Conservation Incentives, Environmental Defense Fund
Eric Lauritzen, Agricultural Commissioner, Monterey County
Lisa Lurie, Agric. Water Quality Coordinator, Monterey Bay National Marine Sanctuary
Dawn Mathes, Agric. Program Manager, Monterey County Agric. Commissioner's Office
Gail Raabe, Agricultural Commissioner, San Mateo County
Dave Runsten, Director of Policy and Programs, Community Alliance for Family Farmers
Ron Ross, Deputy Agricultural Commissioner, San Benito County
Bradley Sullivan, Managing Attorney, Lombardo & Gilles, LLP
Rebecca Thistlethwaite, Associate Specialist UCSC CASFS, and Owner TLC Ranch
Tim York, President, Markon Cooperative
Dr. Devon Zagory, Devon Zagory & Associates

Science Advisory Panel. Scientific and technical input was provided by a team of technical advisers, led by Technical Liaison Mary Bianchi. Science and technical advisors provided input, literature and citations, and review of report content relative to their area of expertise. Considerable conversation within the scientific and technical communities surrounds these issues. However, the issues that are brought forward in this report are deemed ones that deserve continued dialogue to achieve a common goal - to promote food safety and environmental stewardship. Participation in the Advisory Panel does not imply endorsement of this report in its entirety or in any part by the panel members or their organizations.

***University of California Advisory Panel Members:***

Rob Atwill, Cooperative Extension Specialist, Veterinary Science, UC Davis
Brian Anderson, Research Specialist, Granite Canyon Marine Lab, Environmental Toxicology, UC Davis
Mary Bianchi, Cooperative Extension Horticulture Advisor, San Luis Obispo County
Michael Cahn, Cooperative Extension Irrigation and Water Resources Advisor, Monterey County
David Crohn, Associate Professor and Extension Biological Systems Engineer, UC Riverside
Michele Jay-Russell, Food Safety and Security Specialist, Western Institute for Food Safety and Security, UC Davis
Royce Larsen, Cooperative Extension Area Natural Resource and Watershed Advisor, San Luis Obispo County
Michael Payne, Ag Experiment Station Specialist, Western Institute for Food Safety and Security, UC Davis
Trevor Suslow, Cooperative Extension Specialist, Microbial Food Safety, UC Davis
Bill Tietje, Cooperative Extension Area Natural Resource Specialist, Integrated Range Management Hardwood Program, UC Berkeley
Marylynn Yates, Professor of Environmental Microbiology, UC Riverside

***Natural Resource Conservation Service (NRCS) Advisory Panel Member:***

Daniel Mountjoy, Assistant State Conservationist for Field Operations, NRCS

The Nature Conservancy produced this report through a contract with the Produce Safety Project, an Initiative of The Pew Charitable Trusts at Georgetown University. Lead researchers and writers were Dr. Karen Lowell, Dr. Jeff Langholz, and Dr. Diana Stuart. The project was managed by Christina Fischer of The Nature Conservancy.

***Other Individuals Providing Substantial Support***

Many individuals with food safety and environmental quality expertise, including scientists and natural resource agency personnel beyond those listed above, provided support during the researching and writing of the report. In many cases the report authors asked clarifying questions regarding published work, and asked individual researchers to verify that the presentation of their work was complete and accurate. We thank these individuals for their time and effort. Melanie Beretti provided extensive support related to the grower surveys. We also thank more than 100 anonymous growers, handlers, auditors, and others who agreed to be interviewed as part of this study. In particular we thank several individuals who attended multiple plenary meetings to discuss drafts of the report and provided substantial feedback on those drafts, but preferred not to be named. We thank four peer reviewers who provided comments to improve the report, as well as William Most, Emily Sloane, and Rami Shihadeh for research and/or logistical support.

## Foreword

The goal of writing *Safe and Sustainable* was simple: to bring the best available information—and the right mix of people—together to address critical challenges associated with protecting our food supply and the environment. In researching and writing this report one thing became clear: we must pursue both food safety and environmental goals in tandem. Producing safe and nutritious fruits and vegetables is a critical component of public health. So too are grower's efforts to safeguard natural resources such as clean water, clean air, and healthy ecosystems.

Throughout the development of this report, produce growers have resoundingly stated their commitment to produce safe food, their desire to be excellent stewards of natural resources, and their belief that they can do both well – but only if food safety programs effectively integrate resource conservation goals. Today, growers overwhelmingly report being pressured by what appear to be conflicting demands. However, as detailed in this report, we believe "co-managing" for food safety and ecological health is not only possible, but in fact represents the optimal path forward. We owe it to growers and consumers to work together to provide a framework that makes this a reality.

This joint effort has resulted in a long and thorough process. More than 35 expert advisors contributed directly to the drafting of this report, representing many facets of the agricultural industry—from small and mid-scale growers to shippers and buyers—as well as government agencies, environmental non-profits, the legal world, academia, and other related organizations and interests. The research and writing process built extensive networks of cooperation and learning to produce this in-depth report. The project was further advised by top scientific experts in the fields of microbiology, wildlife biology and veterinary science who are engaged in groundbreaking work to define sources of contamination in fresh produce, as well as processes of contamination.

We encourage policy makers and industry leaders at every level to read *Safe and Sustainable* and consider its findings. From legislative offices to corporate boardrooms, it is essential to pay close attention to the research and "on-the-ground" realities represented here. The decisions we make now regarding managing food safety and our natural resources may impact our nation's health and prosperity for generations to come.

Sincerely,

Timothy York, President
Markon Cooperative

Christina Fischer, Project Director
The Nature Conservancy

Gail Raabe
Agricultural Commissioner
San Mateo County

# Abstract and Executive Summary

## Abstract

The safety of fresh produce persists as a pressing national issue. Farmers, environmental groups, and others are working together toward a common goal of promoting food safety and environmental stewardship. Members of these groups have expressed concerns that certain on-farm food safety requirements may do little to protect human health and might in fact damage the natural resources on which agriculture and all life depend. This report analyzes the state of the science behind integration of food safety and ecological health. Drawing from multiple sources – including more than 100 interviews with experts, observations at 68 farms, two large-scale surveys of growers, and a review of more than 250 scientific studies – the report provides the most in-depth examination to date of this topic. The main finding is that growers report yielding to tremendous pressure from auditors, inspectors, and other food safety professionals to change on-farm management practices in ways that not only generate uncertain food safety benefits, but also create serious environmental consequences. Environmental concerns include reduction of water quality, removal of wetland, riparian and other habitat, and elimination of wildlife on and near farm land. Many growers and a wide consortium of regional experts believe that "co-management" for food safety and environmental protection represents the optimal path forward, albeit one that faces several key obstacles. Co-management is defined *as an approach to minimize microbiological hazards associated with food production while simultaneously conserving soil, water, air, wildlife, and other natural resources.* It is based on the premise that farmers want to produce safe food, desire to be good land stewards, and can do both while still remaining economically viable. Although the report focuses on lettuce, spinach, and other leafy greens grown in the Central Coast region of California, its findings reflect concerns across the nation.

## Executive Summary

This report represents the most in-depth examination to date of integrating food safety and environmental protection in agricultural production. The need for such integration occurs in many places and in association with an increasing number of crops. Major national concerns about food safety and ecological health have converged on leafy greens production areas in California's Central Coast region. The local agricultural industry, supporting government and academic professionals, and the environmental community have come together in a collaborative effort to address these concerns.

The confluence of environmental and food safety concerns presents several pressing challenges. It also creates rich opportunities for broad-based coalitions to form around shared concerns, interests, and values. Agricultural producers as well as consumers seek to minimize foodborne illness risks while also conserving the natural resources that make agriculture possible. This includes protecting water quality and preserving the diversity, beauty and utility of natural ecosystems that sustain all of human life. Managing for these multiple goals presents a critical challenge with national implications.

Unfortunately, available information on this challenge varies in quality and is scattered across multiple disciplines. Stakeholders – including industry members, government officials, and environmental and consumer advocates – have lacked an in-depth and objective synthesis of the best available information. This case study fills part of that information gap. Its goal is to aid efforts to make food production safe and sustainable by reviewing the current state of knowledge regarding integration of food safety with ecological health in leafy greens production. Four key questions lie at its core:

1. What is the background and context of the food safety and environmental protection conflict?

2. What is happening "on the ground" with respect to food safety and natural resource conservation practices?

3. What is the current state of the science with respect to these topics?

4. What is "co-management" and which key issues affect its viability?

In answering these questions, the analysis incorporates quantitative and qualitative data spanning both social and natural sciences. Key data sources include:1) more than 100 interviews conducted with regional experts; 2) authors' direct observations on 68 Central Coast farms; 3) a review of more than 250 scientific studies and other relevant publications; and 4) secondary analysis of anonymous mail surveys of 181 growers in 2007 and 154 growers in 2009. The report uses a well established protocol for calibrating different levels of scientific certainty. Terms such as *likely*, *very likely*, and *practically certain* appear throughout the document and reflect increasing levels of confidence regarding expected impacts of on-farm management practices. Confidence is determined by the availability, quality and applicability of scientific evidence.

While numerous important findings appear in this executive summary and throughout the full report, the weight of evidence supports a single overall conclusion:

> *Growers report yielding to tremendous pressure from auditors, inspectors, and other food safety professionals to change on-farm management practices in ways that not only generate uncertain food safety benefits, but also create serious environmental consequences. Many growers and a wide consortium of regional experts believe that "co-management" for food safety and environmental protection represents the optimal path forward, albeit one that faces several key obstacles.*

In terms of context, the Central Coast is nationally significant for its agricultural production and ecological features. Like southern California, western Arizona, the central Mexico highlands, and other major leafy green production areas, the Central Coast region has conditions that support immense biological diversity and position it as an area of national ecological significance. The region's agriculture and environment also play key roles in protecting public health, for example by directly affecting water quality and food safety. Agricultural and ecological features are also the subject of significant regulation and mounting challenges to their long-term viability.

On-the-ground farm management practices have changed in response to food safety concerns. First, growers report being pressured by auditors, inspectors, and other food safety professionals to modify management efforts in ways that cause concern among growers. Second, auditors/inspectors/others most often specify multiple environmental features as food safety risks. For example, 47% (n = 72) of the 154 growers in the above-mentioned 2009 survey reported being told that wildlife was a risk to food safety (including feral pigs, deer, birds, rodents, and amphibians). Additionally, 31% (n = 48) were told the presence of streams, wetlands, and other water bodies near farm fields was a risk to food safety.

The pressures growers face have resulted in changes to agricultural management practices, including impacts on related efforts to conserve soil, wildlife, and water. Anonymous mail-in surveys, authors' visits to dozens of farms, and interviews with more than 80 growers across 2007, 2008, and 2009 provide clear evidence of widespread adoption of conservation practices over the past decade. For example, 91% (n = 165) of respondents to the 2007 grower survey mentioned above reported adopting one or more conservation practice, and the majority reported completing a Farm Water Quality Plan. Seventy-three percent (n = 112) of respondents in the 2009 grower survey indicated they had adopted at least one conservation practice. Growers implement conservation practices for multiple reasons including the maintenance of long-term viability of the natural resource base.

The same sources that provide evidence of adoption of conservation practices also provide clear evidence that in response to pressure from auditors, inspectors and other food safety professionals some conservation practices are now being removed and/or discontinued. For example, twenty-one percent (n = 38) of growers surveyed in 2007 reported that they had removed or abandoned conservation practices. In addition, many growers have taken steps to eliminate wildlife, vegetation, and water bodies near crops in response to pressures from auditors, inspectors, and other food safety professionals. Eighty-nine percent (n = 161) of all growers who responded to the 2007 survey indicated that they had adopted at least one measure to actively discourage or eliminate wildlife from cropped areas in response to expressed food safety concerns. The 2009 grower survey and interviews provide additional evidence. For example 28% (n = 43) of survey respondents stated they had installed fencing to deter wildlife and 22% (n = 34) reported installing bare ground buffers between natural habitat and row crops for the same purpose.

The **science** discussion addresses three questions: What food safety risk do wildlife, non-crop vegetation, and water bodies present? To what extent does removing these three natural resources adversely affect ecological health? What are the food safety consequences of removing or retaining them? The most important finding from the science component is that available data relevant to the three questions posed above are incomplete.

For example, research scientists are beginning to collect survey-based data on pathogen prevalence in diverse wildlife in relation to season and geospatial movements. These data will help to better characterize the role that wildlife might play in direct and indirect pathogen contamination of produce, perhaps in connection with cattle or as independent reservoirs of certain pathogens. The potential for, and relative importance of, direct fecal contamination (e.g., contaminated feces in contact with fresh produce) and indirect contamination of the growing environment (e.g., contamination of water, soil, dust, bioaerosols) by domestic animals and wildlife is an area of active research. The current level of understanding is not sufficient to fully predict risk posed by various contamination processes, nor to identify and implement specific, effective and economically viable mitigation strategies to protect fresh produce from contamination by domesticated and wild animals.

Some studies have demonstrated pathogen presence or vectoring potential in diverse wildlife species, generally at low frequencies. Three investigations following illness outbreaks have found the same pathogens that made people sick to be present in samples collected near fields where the implicated produce was grown. Much of the research to date has helped answer the question, what *can* happen with regard to pathogens in wildlife and domestic animals? Focus has largely rested on the fact that some species of wildlife can carry pathogens, and that they enter crop fields. To fully assess the risks posed by these animals, however, it is necessary to answer the questions: what *does* happen, how much risk does it pose, and what management strategies are appropriate to minimize risk?

The main points here are two-fold:1) contamination processes involving both domesticated and wild animals are not well-described; and 2) the documented ongoing removal of non-crop vegetation and water bodies from farms is based on the assumption that wildlife are attracted to these areas, and that wildlife and their wastes in proximity to crops pose food safety risk. This report's environmental focus has led to a detailed examination of wildlife's potential role in the process of contamination, but several other possible sources of farm-based contamination exist. Leading examples include domesticated animals, water, soil amendments, and workers – all of which are subjects of ongoing research and extensive farm-based food safety practices that lie beyond the scope of this report.

Regarding ecological health, available data from the Central Coast and beyond point to negative environmental consequences of activities reported by growers to be occurring. Reported activities include eliminating or deterring wildlife, reducing non-crop vegetation, and removing natural and engineered water bodies. A large body of scientific literature documents that removal of natural habitat such as wetlands and riparian vegetation leads to negative environmental effects. While quantitative measurement of the impact of on-farm management changes on ecological health was not part of this study, some impacts may be predicted based upon knowledge of both the importance of specific management practices and indicators of changes in their use. Based on evidence reviewed for this report, the following are likely effects of changes in management practices in response to food safety concerns in the Central Coast region:

- adverse impacts on the quality of water for local populations of aquatic organisms such as fish and frogs, as well as on habitat quality for terrestrial species such as birds and mountain lions, due to removal of riparian vegetation;
- adverse effects on water quality, as well as on wildlife populations as integral parts of ecosystems, due to removal of natural water bodies such as wetlands;
- negative environmental impacts on non-target species – including bioaccumulation up the food chain to raptors, bobcats, and other predators – due to use of anticoagulant rodenticides in bait stations;
- compromises in water quality due to reduced use of vegetated treatment systems such as vegetated ponds and grassed waterways;
- increased sedimentation in waterways, leading to reduced aquatic habitat and less capacity to handle floodwaters, due to removal of vegetation and basins that catch sediment before it enters streams and rivers.

This report has not completely considered *cumulative and synergistic environmental effects* related to food safety practices in the Central Coast region, although it is reasonable to expect that they occur. Cumulative and synergistic effects are environmental impacts that result from individually minor but collectively significant actions. The report flags them as issues of concern, but notes that fully documenting cumulative and synergistic effects in the Central Coast region could require extensive research.

With respect to food safety implications, replacement of vegetated buffers with bare ground buffers is of particular concern. To the extent that bare ground allows increased surface water runoff to reach crop land, the potential exists for this practice to increase food safety risk. The risk is especially high in places where range land abuts crop land and during rainfall periods.

Given the changes to practices, and the implications of these changes, what approach do regional stakeholders consider to be a potential path forward? Experts from government, academia, non-profits, and the agriculture industry widely describe co-management as a way to reconcile conflicts between food safety and natural resource protection. Co-management is defined as *an approach to minimize microbiological hazards associated with food production while simultaneously conserving soil, water, air, wildlife, and other natural resources.* It is based on the premise that farmers want to produce safe food, desire to be good land stewards, and can do both while still remaining economically viable. Suggested initial co-management principles include being science-based, adaptable, collaborative, commodity-specific, and site-specific.

Through the process of developing this report, stakeholders have identified key issues that must be considered in efforts to address the challenges of integrating food safety and natural resource conservation goals. Top among these is the presence of numerous private corporate food safety standards, which raise multiple concerns such as: inconsistent interpretation and application of requirements, a spiraling food safety "arms race," lack of transparency in the standards, unclear scientific basis for certain standards, requirements that pressure growers to contravene environmental laws, and a spreading of 'leafy greens' requirements to crops such as Brussel sprouts and artichokes that do not present the same food safety risk because consumers cook them before eating. Other issues are related to mounting liability and litigation risk, potential effects of national food safety standards, the industry's movement into value-added products, and lack of existing scientific data regarding minimizing risk. Understanding and addressing these and other issues will be critical to successful implementation of effective co-management strategies.

Lack of certainty about both food safety risk and threats to ecological health puts growers in a difficult situation. Growers are currently asked to make high stakes decisions with low levels of information, the only certainty being that if anything goes wrong they will be held accountable in both legal and public opinion. That said, even the strongest scientific guidance can only go so far. Individual and societal values play a key role in decision-making at all levels, which stakeholders acknowledge affects co-management success.

Taken as a whole, this case study stands as the most in-depth assessment to date of opportunities and obstacles for making produce safer and more sustainable. It should be of interest wherever people seek to conserve sensitive natural resources, reduce foodborne illness, or both. Although this case study focuses on a single category of produce (leafy greens) and a specific geographical area, the findings and underlying principles may apply across the nation. The report represents an important step toward helping society minimize acute risks of foodborne illness while also preventing chronic dangers posed by ongoing degradation of natural resources.

# CO-MANAGING FOR FOOD SAFETY AND ECOLOGICAL HEALTH IN CALIFORNIA'S CENTRAL COAST REGION

## PART I Introduction and Background

### A. Why This Study?

National concerns about food safety and ecological health are converging in the agricultural fields of California's Central Coast region. On one hand, prevention of foodborne illnesses has emerged as an important national issue (e.g., Booz Allen 2009, United States Government 2009). On the other hand, long-standing awareness of the risks of environmental degradation to both ecological and human health continue to drive efforts to protect wildlife, habitat, and water quality (e.g., U.S. EPA 2009, Worldwatch Institute 2008, TNC 2006).

The confluence of these two concerns presents several pressing challenges. It also creates unprecedented opportunities for broad-based coalitions to form around shared concerns, interests, and values. Both the agriculture industry and consumers have expressed a desire to minimize risks of foodborne illness. But society also wants to conserve the natural resources that make agriculture possible, by protecting the quality of water for human and animal use, and by preserving both the beauty and utility of natural ecosystems. This convergence of societal goals presents a critical challenge with national implications.

Available information on this challenge varies in quality and is scattered across multiple disciplines. Stakeholders – including industry members, government officials, and environmental and consumer groups – have lacked in-depth and objective synthesis of the best available information. This case study attempts to address that information gap. Its goal is to aid efforts to make food production safe and sustainable, considering production of food that addresses the needs of society, the stewardship of the natural environment and the economic viability of the agricultural community. The report reviews the current state of knowledge regarding the integration of food safety with ecological health. The analysis seeks to answer four questions in particular:

1. What is the background and **context** of the food safety and environmental protection conflict?
2. What is happening "on the ground" with respect to food safety and natural resource conservation **practices**?
3. What is the current state of the **science** with respect to these topics?
4. What is "**co-management**" and which key food safety issues affect its viability?

The report synthesizes available information regarding the issues so that interested parties can benefit from a greater understanding of multiple perspectives and current scientific findings. While all interested parties can benefit from its findings, it is important to note that the report reflects perspectives of the Technical Advisory Committee assembled to develop it. By design, the committee focused on activities occurring on or near farms, i.e., the production stage. It did not attempt to include perspectives and representation from large buyers and retailers who comprise other links in the "farm to fork" chain. Nevertheless, the results should be of interest to a diverse set of parties in California and beyond.

### B. Agriculture in the Central Coast Region

California has the largest agriculture sector in the United States (U.S.), producing 50% of the nation's fresh-market vegetables and 78% of its lettuce (CA Agricultural Resources Directory 2009). The Central Coast region of California is one of the most high-value agricultural areas in the state. The region encompasses seven counties: Monterey, San Benito, Santa Cruz, Santa Barbara, Santa Clara, San Mateo, and San Luis Obispo. These counties produce over 200 types of crops and support a $6 billion dollar agricultural industry, according to the latest *Crop Reports* available from county agricultural commissioners' offices. Agriculture is one of the top industries in the region supporting approximately 57,400 jobs in 2006 (CA EDD 2006). Agriculture in the region, especially vineyards and wineries, attracts visitors and contributes towards regional tourism. This report focuses primarily on the production of lettuce and other leafy greens in the Central Coast region. Due to its role as a dominant producer of these commodities, Monterey County is the focus of much of the discussion, even though the issues are not unique to that area. Appendix A provides additional details on Central Coast agriculture and on each of the other topics addressed under subheads in this section.

As the top producers of raw product for bagged salads, growers in the Central Coast and especially in Monterey County have been dramatically impacted by the 2006 outbreak of *Escherichia coli* (*E. coli*) O157:H7 associated with spinach. The outbreak sickened over 200 individuals and resulted in at least 3 deaths (CDC 2006). The ensuing loss of consumer confidence has cost the leafy greens industry more than $350 million by some estimates (Weise and Schmit 2007). Although federal and state officials traced the outbreak to spinach processed in a single facility in San Juan Bautista and sourced from a field in San Benito County, they did not determine how the contamination occurred. The 51-page final report noted that, "No definitive determination could be made regarding how *E. coli* O157:H7 pathogens contaminated spinach in this outbreak." (California Food Emergency Response Team 2007, p.4). The resulting attention on food safety has rippled throughout the Central Coast and largely has been directed towards the most productive regions in the Salinas Valley. Monterey County and the larger Central Coast region have therefore become the center of discussions regarding how to prevent future outbreaks associated with leafy greens.

## C. Ecological Resources in the Central Coast Region

Highly productive agricultural areas are often areas rich in biodiversity and unique natural resources. Like southern California, western Arizona, the highlands of central Mexico and other significant leafy green production areas, the Central Coast region has fertile soils, a moderate climate during the growing season, and topographical diversity that support immense biological diversity and position it as an area of key ecological significance. A combination of coastal systems and topographic diversity makes the region home to a large array of microclimates suitable for several important specialty crops. The Central Coast eco-region contains the largest percentage of bays, estuaries, and salt marshes in California (Davis *et al.* 1998). Waterways in the central portion of the region flow into the Monterey Bay National Marine Sanctuary, the largest marine sanctuary in the United States and an area of exceptional significance for wildlife and commercial fisheries. Rivers include the Salinas, Pajaro, and Santa Maria, plus numerous smaller coastal streams. **Riparian**[1] areas provide essential habitat for birds (including migratory and resident songbirds and waterfowl), mammals, fish (including the federally listed as Threatened steelhead trout (*Oncorhynchus mykiss*), and amphibians (including frogs, toads, snakes and salamanders). The Central Coast region is home to more than 80 species listed or proposed for listing under the U.S. Endangered Species Act.

## D. Protecting Public Health

The Central Coast plays a key role in protecting public health at the local and national levels. The region contributes to national public health by serving as the nation's main source of leafy greens, the consumption of which leads to well documented health benefits (e.g., Goldman 2003, Su *et al.* 2006). Given the 2006 *E. coli* O157:H7 outbreak linked to spinach that was grown here (California Emergency Food Response Team 2007), the region is also on the front lines of implementing on-farm measures to prevent contamination of leafy greens with the pathogens that cause foodborne illnesses. The 2006 incident is only one of numerous outbreaks linked to fresh produce over recent decades (Sicapalasingam *et al.* 2004).

[1] Bold-faced words are defined in the glossary (Appendix C)

Decisions in managing agricultural land play a key role in protecting air, water and soil resources, which are also essential to public health. On-farm conservation practices that effectively remove sediment, excess nutrients, pathogens and pesticides from agricultural drainage water protect both ground and surface water quality. Untreated agricultural drainage water may contain high levels of all of these contaminants and may affect public health by compromising water quality. For example, in yearly well tests by California's Department of Pesticide Regulation, 2.4% (8 out of 328) wells tested on the Central Coast had positive detections for pesticide residues (CDPR, 2008), and 46 Central Coast waterways are listed as impaired, where agriculture is considered one of the contamination sources.[2] Growers are keenly aware that their management strategies have a large impact on the human and natural communities around them, and have made strong efforts to implement conservation practices that protect air, water and soil quality.

### E. The Roles of Voluntary Conservation Efforts and Regulation

Central Coast growers face a complex and escalating array of environmental and food safety regulations, which are detailed in Appendix A. As noted above, the Central Coast region is home to over 80 species listed or proposed for listing under the U.S. Endangered Species Act, which prohibits removal of habitat designated as **Critical Habitat** for these species' survival. Meanwhile, numerous local ordinances restrict vegetation removal and other land modifications, especially in riparian areas and floodplains (Monterey County 2009).

Due to existing water quality problems and threats to natural resources, several agencies have devoted substantial resources towards protecting ecological health in the Central Coast region. The Natural Resources Conservation Service (NRCS) is a part of the U.S. Department of Agriculture and offers technical and financial assistance to growers who adopt conservation practices. These practices serve a variety of purposes including minimizing erosion, reducing the run-off of pesticides, fertilizers and sediment, and promoting wildlife habitat (NRCS 2009). Agencies promote conservation practices through programs such as the Environmental Quality Incentives Program (EQIP), funded through the U.S. Farm Bill. In addition, local Resource Conservation Districts (RCDs) work with growers to adopt conservation practices and other measures to address water pollution and to protect natural resources. Many of these practices use vegetation to filter out and absorb pollutants before drainage water and runoff enters waterways. This vegetation may also serve as wildlife habitat. Neither the NRCS nor the RCDs are regulatory bodies, which means that their programs rely on voluntary grower participation.

Central Coast landowners and growers have voluntarily implemented conservation practices designed to reduce agricultural impacts to waterways and wildlife and to enhance ecosystem health on and near their farms (Resource Conservation District 2007). Regional conservation and farming organizations have become increasingly involved in efforts to reduce the environmental impacts of agriculture in the Central Coast. Several organizations assist growers with installing native vegetation and hedgerows to provide wildlife habitat and reduce agricultural run-off. The award-winning Agriculture Water Quality Alliance formed to further encourage environmental stewardship on farmland. The collaborative effort represents a partnership between the Monterey Bay National Marine Sanctuary, six county Farm Bureaus, the Natural Resources Conservation Service, local Resource Conservation Districts, and the University of California Cooperative Extension (AWQA 2008). Through these and other voluntary efforts, the Central Coast region has become a leading example of cooperation in promoting ecological health and continues to be the focus of efforts to protect water quality, ecosystems, and wildlife.

[2] Full list available from the Central Coast Regional Water Quality Control Board. See:
http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/303dlists2006/epa/r3_06_303d_reqtmdls.pdf

In addition to voluntary programs, regulatory approaches have evolved to protect water quality in the Central Coast. In 1987, Congress amended the U.S. Clean Water Act to include a new Non-point Source Management Program. This program recognizes the need for leadership to address **non-point source** pollution and provides support for states to establish their own methods to do so. The non-point source program in California is administered by the State Water Resources Control Board and nine Regional Water Quality Control Boards (RWQCB). Along with urban area inputs, agriculture is a leading source of non-point source pollution in California. Consequently, a large portion of program resources focus on agricultural pollution. In 2004, the Central Coast RWQCB adopted the "Agricultural Waiver Program," which includes mandatory grower education and promotes the same conservation practices supported by the NRCS. The program also requires growers to participate in water quality monitoring, which may be used in the future to identify pollution "hot spots" and implement enforcement where necessary (Dowd *et al.* 2008).

Overall, Central Coast growers have demonstrated exceptional interest and cooperation in addressing environmental problems associated with agriculture. Central Coast RWQCB staff report that among the roughly 2500 growers in the Central Coast region, approximately 1800 growers (who manage 93% of the total regional acreage) have enrolled in the Agricultural Waiver Program, 1000 growers have completed 15 hours of water quality education, and many of these growers have at least one conservation practice in place.[3] Despite gains and a demonstrated history of voluntary implementation of conservation practices, significant challenges remain, including potential environmental degradation stemming from on-farm food safety practices.

The 2006 outbreak of *E. coli* O157:H7 associated with spinach spawned new measures to address food safety concerns. In 2007, California and national legislative bodies (U.S. Congress and U.S. Senate) both debated newly proposed laws to address food safety but did not pass any legislation. An alternative approach led by industry resulted in a state marketing agreement known as the Leafy Green Products Handler Marketing Agreement (www.lgma.com), with administration by the U.S. Department of Agriculture and the California Department of Food and Agriculture (CDFA). For more information on the LGMA or private food safety programs see Appendix A. Many private firms also adhere to their own food safety standards, including processers, shippers, retailers, and third party auditors. As will be detailed in Part IV, the result is that growers now face new, complex, and often inconsistent measures directed by the produce industry – requirements that occur outside any regulatory oversight or scientific review.

### F. Regarding the Scope and Methods

The following sections explore the extent to which on-farm management practices, promoted either by the produce industry or conservation agencies/organizations, support or undermine food safety and ecological health goals. They analyze current on-the-ground practices relating to food safety and environment, then assess the state of the science underlying these practices. To maximize the quality of this effort, this research process used multiple methods, multiple researchers, and multiple data sources. The three main methods were:1) review of key documents; 2) personal interviews with regional experts; and 3) direct observations conducted at farms and processing facilities. In addition to these qualitative methods, researchers also drew heavily from quantitative data from 154 growers who

[3] According to an August 13, 2008 Regional Board Staff Report (http://www.swrcb.ca.gov/centralcoast/water_issues/programs/ag_waivers/docs/renewal_summary_8_08.pdf), accessed on the regional board website (http://www.swrcb.ca.gov/centralcoast/water_issues/programs/ag_waivers/index.shtml), as of June 30, 2008 1127 growers have completed at least 14 hours of farm water quality education and 1419 growers (representing 379,022 acres of irrigated agriculture) have completed a farm water quality management plan.

answered a mail survey in spring 2009, as well as 181 growers who answered a mail survey in 2007. Appendix B provides additional details on these methods. **Bold-faced** words in this report appear in the glossary (Appendix C).

Considerable scientific uncertainty, opinion, emotion, and politics surround this topic. Thus, this report attempts to gauge the quality of the underlying science regarding specific issues, particularly the amount of evidence available and degree of consensus among experts on its interpretation. The report borrows from a well established protocol for calibrating different levels of scientific certainty. Terms such as *likely, very likely and practically certain* appear throughout the report and reflect increasing levels of confidence regarding expected impacts of on-farm management practices. Confidence is determined by the availability, quality and applicability of scientific evidence. For additional details and an illustrative example, please consult IPCC (2004).

Given how large and complex issues concerning agriculture and the environment are, it was necessary to define the project scope with a clear focus. First, with respect to microbial pathogens, the report applies to a broad range of human pathogens but focuses on pathogenic *E. coli* and *Salmonella*. Second, the geographical focus is on the Central Coast region of California, including the Salinas Valley, although the underlying principles have broad applicability across California and beyond. Third, the analysis applies to a wide variety of crops but has focused on leafy greens, with awareness that many of the contamination issues apply to other produce consumed raw. Fourth, significant outbreaks have occurred dating back to the 1990s, but this report generally focuses on events and practices since the 2006 spinach outbreak. Last, the report focuses on production and harvesting, but acknowledges the critical role of practices during the entire product supply chain including processes associated with fresh-cut / value added, distribution, and end-user handling.

# PART II: Current State of Management Practices

## A. Introduction to Analysis of Management Practices

This section documents on-farm management practices and how they have changed in response to food safety concerns. It focuses on those practices relating to environmental protection, food safety, or both. These are vast topics. For example, the *Commodity Specific Food Safety Guidelines for the Lettuce and Leafy Greens Supply Chain* lists 125 "things to consider" as possible "mitigation steps or practices" to reduce pathogenic contamination (Gorny *et al.* 2006). A more recent document specifies 76 "best practices" for growers to follow during production and harvest stage alone (Leafy Greens Marketing Board 2008). Regarding the environment, Farm Water Quality Plan templates used in the area describe more than 300 on-farm practices to protect water quality (Bianchi, Mountjoy, and Jones 2008). Analyzing this immense set of management practices lies beyond the scope of this report. Instead, the report focuses on the small subset of practices that have generated the most discussion and concern.

This analysis of management practices draws from four primary data sources: 1) interviews with 66 randomly selected growers from Monterey County in 2007 and 2008; a mail survey of 181 Central Coast growers in 2007; 3) interviews with roughly three dozen regional experts in 2009, including 12 growers and representatives from industry, environmental non-profits, and government agencies; and 4) a mail survey of 154 growers in 2009. The use of two quantitative studies, two qualitative sources, and a three-year time period provides a strong foundation for assessing changes in management practices. Multiple sources each provide different perspectives on the topic. Taken as a whole they converge on a single compelling conclusion for Part II: *as a condition to sell their produce, growers report yielding to tremendous pressure exerted by auditors, inspectors, and other food safety professionals to take measures that are potentially damaging to the environment.* The rest of this section covers the four data sources in chronological sequence and summarizes key points from each. It also describes grower concerns and management practices relating to flood waters.

## B. Key Findings from the 2007 Grower Survey

By spring 2007, concerns had arisen about potential environmental impacts of industry-led food safety practices being taken after the fall 2006 *E. coli* outbreak associated with spinach.[4] For example, in a March 19th letter to the region's farm bureaus and agricultural commissioners, the California Department of Transportation commented on observed environmental changes:

> *"Since the E. coli bacteria outbreak this past year, the Department of Transportation (Caltrans) has observed an increased number of property owners and ranchers performing vegetation management measures where the State Right-of-way abuts private property. These efforts include mechanical, manual, and chemical weed and brush control which may be in direct violation of Caltrans vegetation management policies, environmental law and permits obtained by Caltrans from other regulatory agencies."* (cited in multiple sources, e.g., Monterey County Farm Bureau 2007, p.6)

In response to mounting concerns, the Resource Conservation District of Monterey County implemented an anonymous mail survey of growers. The survey provided quantitative documentation of concerns about food safety

[4] For example, the following website displays letters written by local, state, and federal agencies expressing concerns about environmental impacts of new food safety practices:
http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/food_safety.shtml

management practices. A consortium of agriculture entities co-sponsored the research, among them the Grower-Shipper Association of Central California, the Central Coast Agricultural Water Quality Coalition, and the Monterey County Agricultural Commissioner's Office. Exactly 181 growers returned the survey for a response rate of 30% — a rate that is considered by social science standards to be sufficient for the purposes of this analysis. The final report, *A Grower Survey: Reconciling Food Safety and Environmental Protection* (Resource Conservation District 2007) contained several findings, including:

- *Growers actively plan and implement practices to protect the environment.* For example, 91% of survey respondents (n = 165) had adopted one or more **conservation practice(s)**, and the majority had completed a Farm Water Quality Plan.
- *Growers are encouraged to eliminate wildlife, vegetation, and* ***water bodies*** *near crops.* For example, 89% (n = 161) of all growers who responded to the survey indicated that they have adopted at least one measure to actively discourage or eliminate wildlife from cropped areas, in response to food safety concerns.
- *Growers are encouraged to remove* ***non-crop vegetation*** *and* ***conservation practices.*** For example 32% (n = 30) of leafy greens growers who responded had removed non-crop vegetation and 21% (n = 19) reported they had actively removed one or more conservation practice.

The 2007 report also documented the large amount of land potentially affected by this issue (140,000 acres managed by the survey respondents), the extent to which growers are concerned about conflicting demands, and growers' personal thoughts on the situation. For example several growers wrote comments that were included in RCD (2007), among them:[5]

- *"Food safety auditors have been very strict about any vegetation that might provide habitat. We are very concerned about upsetting the natural balance, but we have to comply with our shipper's requests."*
- *"I am afraid many positive environmental programs and practices are going to be abandoned due to retailers/shippers new food safety practices. I am all for the environment and safe food, but feel many new food safety ideas are being driven by fear and uncertainty rather than sound science."*
- *"Ultimately, clean margins and no compost or recycling irrigation water will only hurt the farmers, since they will be liable for ground and surface water pollution."*
- *"We have definitely been put in a conflicting position with new leafy green guidelines and watershed management. For now until more scientific studies produce the needed information I choose to err on the side of food safety, not environmental quality."*

A detailed summary of the survey findings appears in a peer reviewed scholarly journal article (Beretti and Stuart 2008), which is reproduced in Appendix D.

### C. Key Findings from the 2007-2008 Grower Interviews

From fall 2007 to spring 2008, a University of California researcher conducted 66 personal interviews with growers in Monterey County, where the bulk of leafy greens production occurs. Growers of row-crops were selected randomly for interviews. Results appear in a variety of scholarly publications. For example, Stuart (2009a) analyzes interviews with leafy greens growers and includes verbatim comments from several growers expressing regret or concern about the adoption of practices that eliminate vegetation or wildlife.

[5] Direct quotes from anonymous growers appear in several places throughout this report and are based on interview transcripts. They do not pretend to serve as representative samples of all interview data, but rather strive to provide illustrative examples and deeper insights for key topics.

Although interviews focused on qualitative data, the number of interviews conducted makes limited quantitative analysis possible. For example, 84% (n = 55) of interviewees said they had adopted at least one measure to eliminate vegetation and/or wildlife as a result of pressure from auditors, inspectors, or other food safety professionals. Of these, 42% (n = 28) used poisoned bait, 37% (n = 24) removed **non-crop vegetation**, and 21% (n = 14) removed or abandoned **conservation practices** specifically installed for water quality. Approximately 37% (n = 24) reported using traps and 42% (n = 28) reported erecting fences (Stuart 2009b). These quantitative and qualitative data provide solid confirmation of the 2007 mail survey findings.

### D. Key Findings from the 2009 Grower Survey

In early 2009, the Resource Conservation District of Monterey County collaborated with conservation organizations and agricultural industry groups to conduct a follow up mail survey of Central Coast irrigated row crop operations. The survey was designed to obtain clearer understanding of conflicts between food safety and environmental protection. It focused on three objectives:1) identifying the key drivers within the production, marketing, distribution and retail chain that contribute to the challenge; 2) determining which farming operations experience the most pressure as a result of conflicting demands; and 3) assessing if and how the on-the-ground impacts of these challenges have changed over time. Appendix E contains the executive summary of the resulting 68-page report, titled *Challenges to Co-Management for Food Safety and Environmental Protection: A Grower Survey.*

Based on data provided by 154 irrigated row crop operations (from a group of 647 surveyed), the report provided a quantitative, comprehensive snapshot of current on-farm practices and drivers of those practices.[6] The report focused on three categories of practices of particular concern: wildlife management, **non-crop vegetation**, and **water bodies**.[7] This sub-section focuses on management practices within those three categories.

*The relevant overall finding from the 2009 grower survey was that as a condition to sell their produce, nearly half the growers (49%, n = 76) reported being pressured to exclude wildlife, remove non-crop vegetation, and/or remove water bodies from their fields, resulting in substantial on-farm changes.* Growers report that pressure came from auditors, inspectors, and others. As noted in the report "inspectors" are employed by the California Department of Food and Agriculture to monitor for compliance with the Leafy Green Marketing Agreement, "auditors" represent a company that buys produce, and "others" consist mostly of growers' in-house food safety professionals. This section provides specific details supporting the overall finding. It focuses only on portions of the study relevant to this report. Key relevant findings from the survey report include:

<u>Auditors/Inspectors/Others Pressure Growers to Change Practices</u>

- When an environmental feature presents a real or perceived food safety risk growers must take appropriate action to address the food safety concern or risk potential consequences. RCD (2009) provides detailed analysis of common consequences. Examples include auditors deducting audit points, requiring removal of the feature, or rejecting the crop entirely.

[6] From RCD (2009): "Surveys were mailed to irrigated row crop operations in Monterey, San Benito, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, and San Luis Obispo Counties. The survey was mailed out to all known row crop operations using the Central Coast Regional Water Quality Control Board Conditional Waiver Program (Region 3) mailing list of enrolled properties, which covers every county except San Mateo. In San Mateo County the survey was mailed out to all row crop operations identified by the San Mateo County Agricultural Commissioner's Office."

[7] As used in the survey, water bodies and ponds may be either natural or engineered. Some engineered water bodies may occur in areas in which natural ponds, springs or seasonal wetlands have been engineered for agricultural use when land was converted from previous use.

- Approximately half (49%, n = 76) of the survey respondents reported that an auditor/inspector/other had indicated that wildlife, non-crop vegetation or water bodies were risks to food safety. Among all 154 respondents, wildlife (47%, n = 73) was most commonly reported as being indicated as a food safety risk, followed by **water bodies** (31%, n = 48) and **non-crop vegetation** (26%, n = 40).
- Of the 73 respondents who were told wildlife is a risk to food safety, respondents reported the following were noted as animals of concern: feral pig (41%, n = 30); deer (63%, n = 46); birds (57%, n = 42); rodents (73%, n = 53); amphibians (43%, n = 31); other (22%, n = 16).
- Of the 40 respondents who were told non-crop vegetation is a risk to food safety, respondents reported the following vegetation types associated with these concerns: plants in **ditches** or ponds (70%, n = 28); hedgerows or windbreaks (28%, n = 11); **rangeland** (55%, n = 22); natural lands not grazed (55%, n = 22); **wetland** or **riparian** vegetation (55%, n = 22); other (10%, n = 4).
- Of the 47 respondents who were told water bodies are a risk to food safety, respondents reported the following water bodies associated with these concerns: irrigation reservoir (64%, n = 30); **tailwater** and other farm pond (53%, n = 25); stream, river or wetland (51%, n = 24); **agricultural ditch** (45%, n = 21); **sediment** or **stormwater basin** (34%, n = 16); other (0%).

RCD (2009) documents differential treatment of growers based on a variety of factors. For example, growers who adhere to other food safety programs (OFSPs) and sell to either processors or national/international buyers (instead of directly to local markets) were more likely than others to be told that wildlife was a risk to food safety. **Table 1** below provides specific details, including comparisons across species.

**Table 1. Animals Indicated as a Risk to Food Safety: Respondents Adhering to Other Food Safety Programs Selling to Processors, National or International Buyers, or Other Buyers**

(From RCD 2009)

| | % of OFSP Respondents who Sell to Processors or National/International Buyers Told Animals were Risks [1] | % of OFSP Respondents who Do Not Sell to Processors or National/International Buyers Told Animals were Risks [2] |
|---|---|---|
| Feral Pig | 18.8% (n = 6) | 11.7% (n = 7) |
| Deer | 28.1% (n = 9) | 15.0% (n = 9) |
| Birds [3] | 43.8% (n = 14) | 16.7% (n = 10) |
| Rodents [3] | 46.9% (n = 15) | 18.3% (n = 11) |
| Amphibians [3] (e.g., frogs) | 28.1% (n = 9) | 11.7% (n = 7) |
| Other | 18.8% (n = 6) | 5.0% (n = 3) |

Notes:

[1] "OFSP" refers to 92 growers who adhere to "Other Food Safety Programs," e.g., non-LGMA private corporate standards. Of those 92 growers, 32 fit into this column category.

[2] Percentages in this column are based on 60 growers who fit into this column category.

[3] The different results for both Birds and Rodents were statistically significant at $p < 0.05$, and for Amphibians at $p < 0.10$. No other differences were statistically significant.

Actions in Response to Food Safety Concerns about Wildlife

- *One-time* actions reported by respondents to address food safety concerns expressed by auditors, inspectors or others were installing fencing (28%, n = 43) and making **bare ground buffers** (22%, n = 34).[8]
- The most common *ongoing* management activities reported by respondents (used currently) were poison or poison bait for rodents (18%, n = 28), hunting or shooting (15%, n = 23), using **copper sulfate** in irrigation reservoirs to address frogs and fish (5%, n = 8), and using **copper sulfate** in other water bodies to address frogs (3%, n = 5). Six percent (6%, n = 9) of respondents indicated they had taken other actions for wildlife which include: trapping and monitoring bait stations and traps; bird and deer chasers; maintaining no standing water; and informing neighbors of the potential food safety risks associated with their pets.

Actions in Response to Food Safety Concerns about Non-Crop Vegetation

- The *one-time* actions most commonly reported by respondents to have been taken to address food safety concerns about non-crop vegetation expressed by auditors/inspectors/others were clearing **bare ground buffers** (20%, n = 31), removing vegetation from farm ponds and ditches (17%, n = 26), and removing trees and shrubs (16%, n = 25). A total of 13% (n = 20) respondents indicated use of fencing between non-crop vegetation and cropland. Ten percent (10%, n = 15) of respondents indicated that they planted a different crop adjacent to non-crop vegetation. Three percent (3%, n = 5) of respondents indicated that they removed wetland or riparian vegetation.[9]

Actions in Response to Food Safety Concerns about Water bodies

- The one-time actions most commonly reported by respondents to address food safety concerns about water bodies expressed by auditors/inspectors/others were **bare ground buffers** (15%, n = 23), fencing (15%, n = 23), planting different crops adjacent to water bodies (10%, n = 15), and stopping use, draining or filling farm ponds or ditches (9%, n = 14). Five percent (5%, n = 8) of respondents indicated that they drained, diverted, or filled in a natural water body. Three percent (3%, n = 5) of respondents indicated taking other actions to address food safety concerns about water bodies which include: water testing, copper sulfate, discontinued use of irrigation reservoirs, and drained water from the area.

Actions in Response to Food Safety Concerns about Conservation Practices

- In response to food safety concerns expressed by auditors/inspectors/others,12% (n = 18) of all respondents indicated that they had removed a conservation practice (*one-time action*). Practices removed include: vegetated roads, buffers and ditches/waterways; **irrigation reservoirs**, tailwater ponds and basins; compost, animal-based compost and manure; **cover crops**; and habitats.
- In response to food safety concerns expressed by auditors/inspectors/others,11% (n = 17) of all respondents indicated that they had disabled or stopped using a conservation practice (*ongoing action*). Practices taken out of use or disabled include: vegetated buffers and ditches/waterways; irrigation reservoirs, tailwater ponds and basins; compost and manure; cover crops; areas of beneficial insect harborage; and cattle rotation on cropland.

[8] As noted in RCD (2009), "*one-time*" actions include actions such a removal of practices, removal of vegetation, or installation of structures such as fencing. "*Ongoing*" activities include trapping or hunting. Some actions such as installing fencing and bare ground buffers could be one-time or ongoing, but for the purposes of this report are considered as one-time actions.

[9] The illegality of removing wetland and riparian habitat and using copper sulfate to eliminate amphibians may have led to under-reporting.

## E. Key Findings from the 2009 Qualitative Interviews

Research methods for this report also included conducting informal interviews with more than two dozen technical experts representing the agricultural industry, environmental organizations, and government agencies. Many of these experts also served on the project's technical advisory committee. In addition to these technical experts, researchers also interviewed 12 growers. Growers were selected through purposive sampling (Trochim 2000), based on their demonstrated willingness to speak candidly about issues lying at the core of this report, and their representativeness in terms of size (both large/small) and production type (organic/conventional). Interview data do not indicate prevalence of certain experiences and viewpoints, but do offer rich, descriptive information intended to supplement concerns raised during the grower surveys.

The following excerpts from interview summaries illustrate pressures that growers face to deter or eliminate wildlife and/or remove or abandon vegetation or conservation practices. Full summaries of all 12 grower interviews conducted in March-April 2009 appear in Appendix F. These interviews, and the subset of 8 brief summaries below provide deeper insights into growers' experiences with food safety requirements:

- Grower #1[10] (Size category > 3000 acres, mostly conventional): worked with the RCD to install grassed waterways but has had to remove several of them. S/He shares that: "the auditors said they were possible harborage for wildlife and wanted us to either get rid of them or put buffers around them." S/He also shares that they can no longer use reservoirs and have filled several in. S/He has managed to keep some of her/his grassed waterways although they remain a serious problem. S/He states that grassed waterways are always "an audit topic and they argue about it every time." S/He explains how auditors want to see clean ponds with no amphibians, so they use copper sulfate to eliminate frogs and tadpoles.

- Grower #6 (Size category 200-500 acres, conventional and organic): has grassed waterways and catch basins near crop fields. When the auditors from the buyer complain about them s/he tries to explain: "If we didn't catch the tailwater it would just flood over into other fields." Grower has lost business because of these practices. Some buyers will no longer buy crops from her/his fields, so s/he has had to find other buyers with "less stringent standards."

- Grower #11 (Size category 500-1000 acres, all conventional): has been asked by auditors from shippers to remove their conservation practices. Grower used to have grasses in the ditches to reduce erosion, but now keeps them sprayed and clean to keep wildlife out. Grower says that now s/he has more erosion. Grower also puts copper sulfate in all of her/his ponds because the shippers say they must have a pond policy to eliminate amphibians.

- Grower #7 (Size category 1000-3,000 acres, conventional and organic): has removed hundreds of trees and extensive brush around the companies' fields due to pressure from salad processors. Salad plant auditors tell grower: "this tree is too close" and "if you remove this, then I will approve it [the field]." The company also uses blue tablets of copper sulfate in all of their ponds or any standing water because the processors "don't like frogs." Grower shares that processors do not allow them to use their reservoirs anymore so they have bulldozed them over.

- Grower #9 (Size category 1000-3000 acres, all conventional): lost 10 acres of crop, about $32,000, from one incidence of deer intrusion. Grower explains that they have had to build fences all along the [*name redacted to protect anonymity*] river and more will be added. They have been asked to remove riparian

[10] Grower number corresponds to the grower number in Appendix F.

vegetation along the river, but told the auditor (from their shipper) that "it is protected riparian vegetation and we cannot remove it."

- Grower #10 (Size category >3000 acres, conventional and organic): Grower describes why her/his company had to remove conservation practices: "People can't do these practices anymore because they are not allowed to have grasses." Grower explains that for the LGMA it is not so much they are not allowed to have the grasses, but that "the buffer requirements for the LGMA make it unreasonable to install conservation practices." Grower says that you need to have a buffer of at least 10 feet on each side and that "10 feet along a mile and a half is a lot of land that could be farmed." Grower shares that if you need the buffer on both sides that means at least 20 feet out of production on each side. Grower states that keeping conservation practices with these requirements is not practical for business.

- Grower #10 (Size category >3000 acres, conventional and organic): was asked by auditors from a processor to clear brush and put up fences along the [*name redacted to protect anonymity*] river. Grower explains how processors are concerned about foreign matter in the lettuce: seeds from cottonwood trees would get into the romaine lettuce so they were required to cut down the trees. Auditors have also told them to remove extensive shrubs and grass "because they like clean fields." Almost all of their ponds and reservoirs have been bulldozed over because auditors said they were a problem.

- Grower #12 (Size category 200-500 acres, all conventional): has been told by shippers to put out bait stations all along fields, grower states that s/he has close to 1000 bait stations. Grower also put up a fence along the creek. S/He was told by her/his shippers to remove vegetation along the [name redacted to protect anonymity] creek that could serve as habitat and harbor wildlife. They cleared out large sections of the creek: "We probably took out about 90 truck loads of brush from along the creek."

***Identification of Flood Risk and Flood Management Practices.*** Interviews with growers in 2009 also highlight concerns about flooding. For example, one grower interviewed for this report commented, "All of the shippers go beyond the LGMA in their own way. They are stricter regarding flooding and the widths of buffers." Flooding concerns also surfaced in the 2007 quantitative and qualitative data. For example, a participant in the 2007 grower survey described having 23 acres of head lettuce and 2 acres of mixed lettuce rejected by auditors due to contact with [*name redacted to protect anonymity*] river flood water (RCD 2007, Beretti and Stuart 2008). A grower interviewed in 2007 commented, "Fields were flagged out for bird [droppings]. If there was a flood you couldn't plant for 3 years. Ridiculous rule."

Why are growers concerned about food safety when managing for flood prevention, and how do food safety programs alter growers' response to flood management practices? In 2005 the FDA sent a letter to California leafy greens growers stating that product from flooded fields is considered adulterated and not safe for consumption because flood waters may carry human pathogens (FDA, 2005). Citing this letter, current LGMA guidelines require destruction of flooded crops, and recommend a waiting period of 60 days after flooding before re-planting. Soil tests for the presence of microorganisms of significant public health concern, or appropriate indicator microorganisms, may be used to shorten this period to 30 days (LGMA, 2008).

In California's Central Coast region, loss of the standing crop, plus a 60 day waiting period, can result in significant financial loss. Private, corporate food safety standards that go beyond the LGMA requirements can sharply increase these waiting times, resulting in even greater losses. Fresh Express, for example, was reported to require a 5-year post-flood waiting period in a *USA Today* article available on Fresh Express' website at the time of writing and reproduced in Appendix G.[11] Responding to an inquiry made for this report, Fresh Express declined to provide their current standards, but did provide a brief description of them (See Appendix G).

Growers and other landowners cite several reasons other than food safety concerns for wanting to control flooding, among them reducing flood-induced erosion, property damage, and threats to public safety. However, extended periods of lost productivity generate increased financial risk associated with even minor flooding events. This represents a significant new consideration for landowners when contemplating the level of effort to direct at flood control activities such as riparian vegetation management.

Growers report acting on concerns about financial impacts from both loss of crop due to flooding and waiting periods after flooding. New food safety requirements featured prominently in a November 2008 permit request for emergency flood control activities in Monterey County:

> *"Major financial impacts would result from the temporary loss of available agricultural lands for crop production subjected to a flood. Under the California Leafy Green Products Handler Marketing Agreement (LGMA), rigid food safety standard controls are now in place for production of crops in recently flooded areas. The LGMA standard states the grower/landowner must till under any existing flooded areas, allow the soil to dry sufficiently, and perform active tillage therein for at least 60 day following the receding of the flood water before planting a new crop. This tillage work is required to provide additional protection against the survival of pathogenic organisms."*
>
> (Army Corps of Engineers Public Notice, November 2008, pg. 2)

The LGMA guides growers to consult with appropriate regulatory agencies prior to implementing flood control strategies in environmentally sensitive areas adjacent to crop land (LGMA 2008, including its Appendix Z). It is not known whether private corporate standards provide similar guidance, nor the extent to which such guidance is followed.

Based on the above, it is reasonable to assume that growers will consider food safety related risks when making flood control decisions, and that such consideration may lead to more channel clearing and riparian vegetation management than was previously considered necessary to address flood risks. Should this be the case, it could lead to substantial adverse impacts on affected rivers and streams. These waterways and the associated riparian vegetation serve as regional wildlife corridors and habitat for steelhead and other aquatic species (Entrix Inc. 2009, Moyle 2002, Smith 2007).

***Part II Conclusion***. Overall, the 2009 qualitative interview data, combined with the grower interviews from 2007-2008 and quantitative survey results from both 2007 and 2009, provide compelling evidence of changes in management practices due to food safety concerns. These changes influence management of wildlife, water bodies, non-crop vegetation, and flood risk. Part III explores the implications of the management changes that growers report taking to address food safety issues. Specifically, the following section explores the science behind this subset of practices in order to clarify implications for both food safety and ecological health.

[11] In addition to Appendix G, please see Schmit (2006) at
http://www.freshexpress.com/assets/news/freshnews/usa061101.pdf

## Part III: State of the Science – Implications of Changes to Management Practices

### A. Defining Risks in a Local Context

As indicated above, growers report being told that wildlife, non-crop vegetation and water bodies pose a risk to food safety. They also indicate that proximity of domestic animals and their waste products to crop production areas is considered a risk. The following section begins by reviewing information regarding factors that growers report they have been told are risks for food safety, and reviews scientific literature that addresses risk from these factors. The review then considers available information to assess the impact of changes in management practices to address food safety concerns – deterring or eliminating wildlife, reducing use of non-crop vegetation or altering use of water bodies – on ecological health and food safety objectives in the Central Coast region.

Much of the discussion here summarizes review of relevant literature, reports, and other information sources that are presented with full citations and in more detail in Appendices H and I. Wherever possible, research done in the Central Coast region, under conditions representative of local, irrigated row crop production systems, is discussed to help provide the most relevant assessment of the effectiveness of local management practices.

### B. Evidence of Food Safety Risk From On-Farm Factors

***Risks from Wildlife:*** Wildlife has received considerable attention in efforts to identify sources of *E. coli* O157:H7 and other pathogens in fresh produce. However, data relevant to food safety risk from wildlife is scarce and incomplete (Atwill, 2008).

Table 2 summarizes details about the methods, sample size, and factors reported in 52 studies relevant to pathogens in wildlife. These studies demonstrate the range of research areas, species, and methodologies used to investigate the role both wild and domestic animals may play in contamination processes. See Appendix I for a detailed explanation of how these studies were identified and selected.

Prevalence studies of pathogens in cattle or other domestic animals typically represent the infection rate in the population as a whole. Population size is known, as is percent of the population sampled. In the vast majority of studies investigating pathogen prevalence in wildlife, population size and percent of the population sampled are not known. For example, if 100 fecal samples are collected after deposition, in many instances it is not known whether this represents fecal samples of 100 animals, or fecal samples of 25 animals defecating four times each. Also, methods of collection, knowledge of sample age and condition, duration of pathogen shedding from infected animals, magnitude of infection (number cfu/g fecal matter), and possibility of contamination after deposition are usually unknown. Because of these uncertainties, the data summarized in Table 2 should be seen as a guide for future study, not a statement of risk.

Few studies have been conducted in North America, and particularly in California or the Central Coast region. Pathogen prevalence and movement may depend upon the environment in which animals live and coexist. For this reason, full assessment of the risk wildlife and their wastes may pose to food safety must include studies in the relevant growing environment.

Research to date primarily addresses whether various species of animals are capable of carrying human pathogens. Contamination processes might include direct transfer of pathogens to fresh produce through fecal deposition directly onto plants. Other contamination processes might involve contamination of the growing environment (e.g., water, soil, dust, bioaerosols), elements of which may subsequently come in contact with crops. The relative importance of these mechanisms in recent contamination processes remains unclear. Without information that describes the contamination process, it is extremely difficult to assess the risk posed by the presence of pathogens in domesticated and wild animals, particularly in wildlife populations where sample collection is more challenging.

**Table 2. Summary of Select Studies Examining Pathogens in Wild and Domestic Animals**

| Citation | Findings/Comments |
|---|---|
| **Adesiyun *et al.* 2009** | ***E. coli*** O157, *Salmonella*, ***Campylobacter***<br>Bats representing 12 species from 27 locations across Trinidad and Tobago were trapped and euthanized. A total of 337 fecal samples from the euthanized bats were collected. Four of 377 (1.1%) samples were positive for *Salmonella*. None of 377 samples were positive for *E. coli* O157 or **Campylobacter**. Species of bats sampled included *Artebius* sp., *Carollia perspicillata, Desmodus rotundus, Diaemus* youngi, *Glossophaga* sp., *Molossus major, Molossus ater, Mormoops* sp., *Noctilio leporinus, Phyllostomus hastatus, Phyllostomus discolor, and Pteronotus parnelli.* |
| **Atwill *et al.*, 1997** | ***Cryptosporidium* spp., *Giardia duodenalis***<br>Examined shedding potential and prevalence of *Cryptosporidium* spp. and *Giardia duodenalis* in feral swine in Coast Range of north and central California. A total of 221 animals from 10 populations were live trapped or shot, and fecal samples collected for analysis. 5.4% (12/221) of the animals were shedding *Cryptosporidium* and 7.6% (17/221) were shedding *Giardia*. Information about population density of the swine, association with cattle, age/gender/sex of the individual animal was all collected. |
| **Beutin *et al.*, 1993** | **STEC**<br>Domestic animals in Germany were sampled in a number of locations and the frequency of VTEC[12] carriers was recorded. All animals were healthy. Samples were collected by rectal swab[13] or directly from the colon in slaughtered animals. 80 of 120 (66.6%) sheep sampled from 6 populations were positive; 9 of 120 (7.5%) domestic pigs sampled from six populations were positive; 37 of 66 (56.1%) goats from 4 populations were positive; 9 of 65 (13.8%) cats from two populations were positive; and 3 of 63 (4.8%) dogs from two populations were positive. All animals were from private farms, university institutes or the Berlin Zoological Garden, except the dogs and cats, which were from private owners or the Berlin Society for the Protection of Animals. |

[12] STEC (Shiga toxin-producing *Escherchia coli*) and VTEC (Verotoxin (VT [Shiga-like toxin] *Escherichia coli*) are used interchangeably by researchers. STEC is generally used by U.S. based researchers, VTEC by European based researchers.

[13] It is important to note that direct comparisons between studies are problematic because of the lack of standardized methods. Proportion of the population sampled impacts the margin of error of reported results. The size (weight) sample tested and the microbiological methods used may also influence the sensitivity of the test. Additionally, improvements in laboratory detection methods in recent years raise questions regarding negative results from older surveys of pathogen prevalence in wildlife populations.

| Citation | Findings/Comments |
|---|---|
| **Branham *et al.*, 2005** | ***E. coli* O157, *Salmonella***<br>Sampled for *E. coli* O157:H7 and *Salmonella* in populations of deer and livestock grazing the same range land in Texas. Deer were sampled after hunter kill. Some information about spatial relationships of water sources, animal grazing areas is given in the discussion. *E. coli* O157:H7 found in 1 of 80 (1.25%) cattle; 1 of 82 (1.22%) sheep; 0 of 81(0%) goats; and 0 of 26 fecal or rumen samples from white tailed deer (samples of each from 26 animals). One of 20 (5%) water samples was positive for *E. coli* O157:H7. *Salmonella* found in 1 of 80 (1.25%) cattle; 6 of 82 (7.32%) sheep; 3 of 81 (3.7%) goats; 0 of 26 white tailed deer fecal samples; 2 of 26 (7.69%) white tailed deer rumen samples; and 1 of20 (5%) water samples. |
| **Chapman *et al.*, 1997** | ***E. coli* O157**<br>Study of cattle, sheep, pigs and poultry in England. Tested 400 cattle each month over an entire year and found 13.4% of beef cattle and 16.1% of dairy cattle tested positive for *E. coli* O157:H7; in spring/summer up to 36.8% of cattle tested positive for *E. coli* O157:H7. Also tested 1000 each of sheep, pigs and poultry over the same period. *E. coli* O157:H7 was isolated from 2.2% of sheep, 0.4% of pigs, and 0% of chickens. |
| **Cizek *et al.*, 1999** | ***E. coli* O157**<br>Fecal samples were collected from cattle, feral pigeons, domestic sparrows (no further description given) and rodents. 72 of 365 (20%) of cattle fecal samples; 0 of 50 (0%) of pigeon samples; 0 of 20 (0%) of sparrow samples; and 4 of 10 (40%) of Norwegian rat samples (*Rattus norvegicus*) were positive for *E. coli* O157:H7. |
| **Cody *et al.*, 1999** | ***E. coli* O157**<br>Deer (species not noted) feces collected near an orchard in California from which *E. coli* O157:H7 contaminated apples had been used to make juice tested positive for *E.coli* O157:H7. Amount of fecal material collected is not noted. Consumers of the juice became ill from the contamination. |
| **Compton *et al.* 2008** | ***Salmonella***<br>Ten *Salmonella enterica* serotypes were found in fecal samples from raccoons (*Procyon lotor*) in Pennsylvania. Samples were collected from live, anesthetized animals caught in traps. *Salmonella* was isolated in 55 of 738 (7.4%) of the samples collected over a two year period. |
| **Converse *et al.*, 1999** | ***E. coli* O157, *Salmonella* spp., *Campylobacter***<br>Fecal material from Canada geese resident in non-agricultural areas in Massachusetts, Virginia and New Jersey was collected three times over approximately 2 months from 12 study sites. Ten samples were collected each of the three sampling sessions from each site. Samples were collected from the ground and were of unknown age at the time of collection, but were noted to be "fresh". Some samples were marked and allowed to remain for five days before collection and analysis. No movement patterns of the geese populations sampled noted. Two of 360 samples (0.6%) were positive for *Salmonella* spp., none of the samples were found positive for *E. coli* O157:H7 or *Campylobacter*. |
| **Dunn *et al.*, 2004** | ***E. coli* O157**<br>Prevalence of *E. coli* O157:H7 in hunter-harvested white-tailed (*Odocoileus virginianus*) deer in Louisiana, U.S.A. was 0.3% (n=338). In August 2001, *E. coli* O157:H7 was detected in one of 55 deer (1.8%) from the captive herd, which was fed a grain concentrate. Prevalence over the 1-yr period for the captive herd was 0.4% (n=226). |

| Citation | Findings/Comments |
|---|---|
| Faith *et al.* 1996 | ***E. coli* O157**<br>Researchers sampled dairy cattle manure to test for prevalence of *E. coli* O157:H7 in the animals. In a prevalence study, 10 of 560 calves (1.8%) tested positive for *E. coli* O157:H7. In a follow up study, in addition to bovine fecal samples, a total of 302 environmental samples including feed, water, and non-bovine animal feces were tested. The 18 non-bovine animal feces tested included cat, dog, pig, rabbit, and raccoon (number of each not specified). None of the non-bovine samples were positive. Three percent (3/101) animal drinking water samples were positive. Prevalence in the bovine feces during the follow up study was 3.7% (19/517). |
| Fenlon, 1981 | *Salmonella*<br>Found prevalence of *Salmonella* in seagull (*Larus* spp.) feces of 12.9% for 1,242 samples. Samples were taken at various locations in Scotland in open areas, by lakes, and by sewage outfalls. Results showed that gulls feeding at sewage works had higher rates (17-21%) of carriage of pathogens than those elsewhere. |
| Fischer *et al.*, 2001 | ***E. coli* O157**<br>Did a two year study in southeast states in the U.S. with sampling in a total of 11 sites. Samples collected from the rectum of hunter kill deer or from the ground. None of 310 (0%) samples of fecal material collected from the ground (age unknown, but described as fresh) were positive for *E. coli* O157:H7. Three of 469 (0.64%) fecal samples collected from free-ranging deer (hunter kill) were positive in the first year. All 3 were from same sample site. Thirteen of 305 (4.3%) cattle sampled from an adjacent area (sampling method not stated) to the area in which positive *E. coli* O157:H7 results for deer were found were positive for *E. coli* O157:H7. While both the cattle and the deer found to carry *E. coli* O157:H7 in their feces came from the same sample site, there was not a match between the *E. coli* O157:H7 strains found in each. In a subsequent sampling of all 11 sites, one of 140 (0.7%) deer samples was positive. |
| Garcia-Sanchez *et al.*, 2007 | ***E. coli* O157**<br>Used rectal swabs to sample wild populations. 206 red deer (*Cervus elaphus*), 20 roe deer (*Capreolus capreolus*), 6 fallow deer (*Dama dama*) and 11 mouflon (*Ovis musimon*) in southwestern Spain were tested for *E. coli* O157:H7. Three of 206 red deer (1.5%) were positive for *E. coli* O157. All other samples were negative. |
| Gaukler *et al.*, 2009 | ***E. coli* O157**, *Salmonella*<br>Used tags and radio transmitters on European starlings (*Sturnus vulgaris*) in Kansas to explore movement of these birds among feedlots and roosting spots. All cloacal swabs (n=434) were negative for *E. coli* O157:H7. Three out of 434 samples (0.7%) tested positive for *Salmonella*. Distances traveled by the birds were recorded for those collected from tagged individuals. Average distance from roosting site to feedlot was 19 km, though some radio tagged individuals moved as far as 40 km from the capture site, and one bird was found 1,287 km away. |

| Citation | Findings/Comments |
|---|---|
| **Gray *et al.*, 2007** | ***E. coli* O157**<br>Authors conclude that tadpoles orally inoculated with *E. coli* O157:H7 and housed in a flow through aquarium in a lab study did not become infected, while inoculated metamorphs (young frogs recently developed from tadpoles) housed in lab tanks not connected to a flow through system did become infected. None of 23 tadpoles' organ samples showed positive results for *E. coli* O157. 54% of 24 metamorphs, housed in a stagnant tank after inoculation, had positive results for organ tests of *E. coli* O157. The two metamorphs sampled on the last day of the study (21 days after inoculation) were negative for *E. coli* O157 in their organ tissues. Small sample size, differences in water condition for tadpoles and metamorphs, and imperfect replicates of natural environments make extrapolation to field settings problematic. |
| **Hancock *et al.*, 1998** | ***E. coli* O157**<br>Research conducted in the Pacific Northwest tested for *E. coli* O157 in wild birds on cattle ranches. One of 200 (0.5%) bird feces samples from 12 farms tested positive for *E. coli* O157:H7. Feces were collected from roosting spots, not directly from birds; species not described. None of 300 rodents from 11 farms were found to harbor *E. coli* O157:H7. Rodents were live caught and euthanized for sampling; species not given. None of 34 wildlife fecal samples from 6 farms positive for *E. coli* O157. Species of wildlife not listed; feces of unknown age. |
| **Henzler and Opitz, 1992** | *Salmonella*<br>715 mice and rats were sampled from 10 poultry farms with 16.2% culture-positive for *Salmonella* enteritidis. *Salmonella* enteritidis was shown to persist for at least 10 months in an infected mouse population. Authors conclude that mice may be important amplifiers of disease in egg-laying farms. |
| **Heuvelink *et al.* 2008** | ***E. coli O157, Salmonella, Cryptosporidium, Giardia***<br>Wildlife samples were collected over a 22 month period in The Netherlands. A total of 897 fecal samples was collected. Prevalence of *E. coli* O157 was 13.8%, *Salmonella* was 0.1% and *Campylobacter* was 0.5%. *Campylobacter* was isolated mainly from fecal samples collected from birds, including corvidea (59.8%), and meadow birds and waterfowl (22.4%). A subset of 247 samples was also analyzed for *Cryptosporidium* and *Giardia*; none were positive for *Cryptosporidium*, one roe deer sample was positive for *Giardia*. (Information extracted from abstract only) |
| **Hussein, 2007** | **STEC**<br>Reviewed literature of prevalence of STEC (Shiga toxin-producing *E. coli*, of which *E. coli* O157:H7 is one) in beef cattle. The review found prevalence rates of *E. coli* O157:H7 ranged from 0.3% to 19.7% in feedlots and from 0.7% to 27.3% on pasture. Prevalence rates for non-O157:H7 STEC were 4.6% to 55.9% in feedlots and 4.7% to 44.8% on pasture. The authors note that non-O157:H7 should also be considered in addressing pathogen risks in beef products. |
| **Janisiewicz *et al.*, 1999** | ***E. coli* O157**<br>Fruit flies were contaminated with *E. coli* by allowing them to walk on an ager plate with the bacteria. Seven of nine fruit flies were contaminated after 2 hours exposure to *E. coli*; all fruit flies were contaminated after 6 or 24 hours. In a separate experiment, transfer of *E. coli* F-11775 (a non-pathogenic strain of *E. coli* found to grow similarly to *E. coli* O157:H7 on apples) to wounded apple tissue was demonstrated to be possible. Four, three and all six apples in the glass dome experimental container were contaminated after exposure to the fruit flies after 6, 24 and 48 hours. |

| Citation | Findings/Comments |
|---|---|
| Jay *et al.*, 2007 | ***E. coli* O157**<br>See discussion in text box. Sampling results for *E. coli* O157 in a irrigated row crop production area in California 26/77(33.8%) of cattle feces; 0/10 (0%) water troughs; 13/87 (14.9%) feral pig feces;3/79 (3.8%) surface water samples; 3/37 (8.1%) soil/sediment samples; 0/18 (0%) well water samples. |
| Jijon *et al.* 2007 | ***E. coli* O157, *Salmonella***<br>Fecal samples collected from wild animals taken to two wildlife rehabilitation centers in Ohio were analyzed for *E. coli* O157 and *Salmonella*. Samples were taken within 3 days of arrival in the center. None of the animals tested were positive for *E. coli* O157. A total of 8 of 71 samples were positive for *Salmonella*. The researchers note that acquisition of *Salmonella* at the rehabilitation facility itself was likely in some of the infections, perhaps in as many as half the cases (Dr. Jeff LeJeune, DVM, Dipl. ACVM, personal communication). Number of positive samples/number of samples from the species were as follows: 0/1 Turkey vulture (*Cathartes aura*), 0/4 Eastern cottontail (*Sylvilagus floridanus*), 3/7 (43%) Opossum (*Didelphis virginiana*), 0/4 Common raccoon (*Procyon lotor*), 0/4 Canada goose (*Branta canadensis*), 0/2 Mallard duck (*Anas platyrhynchos*), 0/14 Red-tailed hawk (*Buteo jamaicensis*), 1/1 (100%) Harris's hawk (*Parabuteo unicinctus*), 0/3 Cooper's hawk (*Accipiter cooperii*), 1/8 (12.5%) Eastern screech-owl (*Otus asio*), 0/3 Barred owl (*Strix varia*), 0/1 Great horned owl (*Bubo virginianus*), 0/6 American kestrel (*Falco sparverius*), 0/3 Mourning dove (*Zenaida macroura*), 0/1 Jumping meadow mouse (*Zapus hudsonius luteus*), 0/1 White-tailed deer (*Odocoileus virginianus*), 1/3 (33.3%) Woodchuck (*Marmota monax*), 2/4 (50%) Eastern gray squirrel (*Sciurus carolinensis*) and 0/1 Eastern fox squirrel (*Sciurus niger*). |
| Johnsen *et al.*, 2001 | ***E. coli* O157**<br>Intestinal contents from 1,541 cattle, 665 sheep, and 1,976 pigs in Norway were analyzed for *E. coli* O157:H7. *E. coli* O157:H7 was present in 0.35% of cattle, 0.24% of pigs and 0% of sheep. |
| Keene *et al.*, 1997 | ***E. coli* O157**<br>Consumption of venison jerky by a hunter and family members in Oregon led to *E. coli* O157:H7 infection. *E. coli* O157:H7 was recovered from 3 of 32 (9%) of black tailed deer (*Odocoileus hemionus columbianus*) fecal pellets and none of 9 elk (species not given) fecal pellets collected in forest land near where deer had been hunted. In samples collected 4 months later, none of three deer samples, and none of 70 cow fecal samples collected from a nearby ranch were positive. |
| Kirk *et al.*, 2002 | ***Salmonella***<br>Sampled water in troughs from weaned dairy calves in California. *Salmonella* was found in 4 of 48 dairies in fall 1998 and 8 of 37 dairies in summer 1999. Methods of managing water (continuous filing vs. valve) may affect likeliness of *Salmonella*. |
| Kullas *et al.* 2002 | ***E. coli* O157**<br>Researchers collected a total of 397 Canada goose (*Branta canadensis*) fecal samples from four study sites over approximately 11 months. An aggregate sample was collected once every four weeks from a marked area at four sites around Fort Collins, CO. The sample area was raked clean for three weeks in a row; the sample was collected in the fourth week. Samples were also collected from outside the transect area. No *E. coli* O157 strains were identified, though 6% of the samples were classified as EHEC strains. |

| Citation | Findings/Comments |
|---|---|
| LeJeune *et al.*, 2008 | ***E. coli*** **O157**<br>Radio tagged European starlings in Ohio, and also sampled entire gut of 316 birds and found 7 out of 316 (2.2%) sampled were positive for *E. coli* O157:H7. 48 out of 1869 cow manure samples collected from the farms where the birds were captured tested positive for *E. coli* O157:H7. |
| Lillehaug *et al.* 2005 | **STEC, *Salmonella*, *Campylobacter***<br>Fecal samples from wild red deer, roe deer, reindeer and moose were provided during hunting season in Norway. None of 135 red deer, 0 of 127 moose, 0 of 206 roe deer, and 0 of 150 wild reindeer were positive for STEC. 0 of 135 red deer, 0 of 127 moose, 0 of 196 roe deer and 0 of 153 wild reindeer were positive for *Salmonella*. 0 of 82 red deer, 0 of 82 moose, one of 38 (2.6%) roe deer and 0 of 150 wild reindeer were positive for *Campylobacter*. |
| Nagano *et al.* 2007 | ***E. coli*** **O157, *Salmonella*, *Shigella*, *Yersinia*, *Cryptosporidium***<br>A total of 464 fox (*Vulpes vulpes*) were shot and killed during a vermin cull throughout Ireland in 2003. Post-mortem rectal samples were collected from a randomly selected group of 124 fox. All samples were negative for *E. coli* O157, *Salmonella*, *Shigella*, and *Yersinia*. Ten (8.1%) of the samples were presumptively positive for *Cryptosporidium*. |
| Nakazawa *et al.*, 1999 | ***E. coli*** **O157**<br>Rectal fecal swabs from 221 pigs from 35 farms in Japan were tested for *E. coli* O157:H7. Three pigs from three different farms tested positive (1.3%). |
| Nielson *et al.*, 2004 | **STEC**<br>A total of 446 fecal samples collected from animals found near cattle and pig farms in Denmark were tested for STEC. These included 244 wild bird samples (the most common species represented were barn swallows (*Hirundu rustica*), tree swallows (*Passer monanus*), house sparrows (*Passer* domesticus), and blackbirds (*Turdus merula*)). Four birds (4/244, 1.6%) were found positive for STEC. The positive birds were two tree sparrows, one barn swallow and one starlings (*S. vulgaris*). Two rodents (2/10, 20%) were found positive, and 0 out of 6 pooled insect samples were found positive. |
| Olsen *et al.* 2002 | ***E. coli*** **O157**<br>Following an outbreak of *E. coli* O157 linked to a contaminated municipal water system in Alpine, Wyoming researchers tested deer and elk (species not noted) fecal samples. None of five deer and elk samples taken from an area near the underground spring that served as a water supply source for patients who had become ill were positive for *E. coli* O157. |
| Palmgreen *et al.*, 1997 | ***E. coli*** **O157, *Salmonella*, *Campylobacter spp.***<br>Stool samples were collected from 50 seagulls and 101 passerines (land birds) that were just entering Sweden from their wintering grounds. Samples were analyzed for *Salmonella*, *Campylobacter* spp., and *E. coli* O157:H7. Two of 50 (4%) seagull samples were positive for an antibiotic resistant strain of *Salmonella*; three of 101 (2.9%) passerine samples were positive for *Campylobactor jeuni*, and no samples from either type of bird tested positive for *E. coli* O157:H7. |

| Citation | Findings/Comments |
|---|---|
| **Parish, 1998** | ***Salmonella***<br>Following an outbreak of *Salmonella* Hartford in people drinking orange juice purchased at a theme park in Florida, environmental samples near the juice processing facility were collected. Samples were collected from sump water, dried frog feces, four tree frogs (*Hyla cinerea*) and a toad (*Bufo terrestris*). No *Salmonella* was found in sump water or dried frog feces. The toad tested positive for *Salmonella* Newport and Hartford, but not the same strain of *Salmonella* Hartford found in the outbreak patients. Tree frogs were positive for *Salmonella* Newport. Author does not specify how many frogs were positive. |
| **Pedersen *et al.* 2006** | **STEC**<br>Cloacal swabs were collected from a total of 406 rock pigeons (*Columba livia*) live trapped or sampled immediately after being shot in. Pigeons from seven locations, including both urban and dairy farm settings, were sampled. No STEC was detected in the 406 samples. *Salmonella* was detected in nine of 106 (9%) of pigeons samples collected from a dairy environment, and none of 171 of samples collected from urban pigeons. The prevalence for *Salmonella* in all samples was 3% (9/277). Environmental samples in the dairy farm setting were also positive for *Salmonella* as follows: manure (8/120 samples, 7%), water (2/120, 2%), feed (11/120, 9%). |
| **Renter *et al.* 2001** | ***E. coli* O157**<br>Fecal samples from free range white-tailed deer (*Odocoileus virginianus*) in Nebraska were collected by hunters from dead animals when they weighed in with their kill. *E. coli* O157:H7 was cultured from four (0.25%) of 1,608 total samples submitted. |
| **Renter *et al.* 2003** | ***E. coli* O157**<br>Fecal and water samples collected in range cattle environments in Kansas and Nebraska over an 11 month period were analyzed for *E. coli* O157. 92 of 9122 (1.01%) cow fecal samples and 14 of 4083 (0.34%) water samples were positive for *E. coli* O157. Of 521 wildlife fecal samples 0 of 230 raccoon, 0 of 141 deer, 0 of 100 coyote, 0 of 9 bird (species names not given), 0 of 16 unknown species samples were positive. One of 25 opossum (*Didelphis virginianus*) tested positive. The same subtype of *E. coli* O157 was identified in all samples. Cow fecal samples were collected from cows observed defecating and were of known age. Wildlife samples were collected from the ground as scat during cattle sampling visits, and were also collected by local hunters and trappers. |
| **Renter *et al.* 2006** | ***Salmonella***<br>Fecal samples from free range deer (*Odocoileus virginianus*) in Nebraska were collected by hunters from dead animals when they weighed in with their kill. A subset of 500 of the 1,608 samples submitted by hunters was analyzed for *Salmonella* content. One percent (5/500) of the samples were positive for *Salmonella*. The authors state that the serovars recovered are pathogenic to humans and animals. |

| Citation | Findings/Comments |
|---|---|
| **Rice *et al*. 2003** | ***E. coli* O157**<br>The authors of the study solicited or collected and cultured feces from a variety of wildlife whenever the opportunity arose. No further details of sample collection or treatment procedures given, nor are Latin names given for the following animals for which fecal matter was collected. Species name is followed by the number of positive samples/number of samples: white-tailed deer (5/630, 0.79%), elk (0/244), bison (0/57), bighorn sheep (0/32), antelope (0/1), Canada goose (0/121), trumpeter swan (0/67), gull (0/150), duck (0/20), starling (0/124), wild turkey (0/83), coyote (0/7), rodent (0/300), pooled flies (2/60, 3.33%), and fish (0/4). |
| **Richards *et al*., 2004** | ***Salmonella***<br>Sampled animals brought to a wildlife rescue center, including: 34 eastern box turtles (*Terrapene carolina carolina*), 14 eastern painted turtles (*Chrysemys picta picta*), 14 snapping turtles (*Chelydra serpentina*), 6 black rat snakes (*Elaphe obsoleta obsoleta*), 2 redbelly turtles (*Pseudemys rubriventris*), 2 yellowbelly sliders (*Trachemys scripta scripta*), 2 eastern garter snakes (*Thamnophis sirtalis sirtalis*), and 1 eastern river cooter (*Pseudemys concinna concinna*). All cultures were negative for *Salmonella* spp., which the authors report is in contrast to the high prevalence of *Salmonella* cloacal shedding reported in captive reptiles but similar to previous reports in free-living North American reptiles. |
| **Samadpour *et al*. 2002** | ***E. coli* O157**<br>After an illness outbreak traced to a recreational swimming lake in Washington state, fecal, water, sand, soil and sediment samples were collected and tested for *E. coli* O157. One of 20 (5%) of duck feces sampled, and 2 of 51 (3.9%) of water samples were positive for the outbreak strain. All other fecal samples collected including 4 cow, 1 coyote, 2 deer, and 1 rabbit fecal were negative. |
| **Sanchez *et al*., 2009** | ***E. coli***<br>Tested for Shiga toxin-producing *E. coli* with pathogenic potential (not *E. coli* O157:H7) in wild ruminants in Spain (elk, European roe deer, fallow deer, mountain sheep) 58 of 243 (23.9%) samples were positive. Authors state that the STEC detected have the potential to be serious human pathogens. |
| **Sanderson *et al*. 2006** | ***E. coli* O157**<br>Sampled cattle feces, water, feed, bird feces and houseflies in a feedlot cattle environment over a 13 week period. Six of 165 (3.6%) of bird fecal samples were positive for *E. coli* O157. Samples were of unknown age, bird species were not noted. Housefly (species not given) samples were collected by a swoop net in the feedlot environment. 53 of 1,540 (3.4%) were positive for *E. coli* O157. |
| **Sargeant *et al*., 1999** | ***E. coli* O157**<br>Collection of fecal samples from 2 Kansas ranches where white tailed deer (*Odocoileus virginianus*) and cattle share range land. Fresh fecal samples (n=212) from free ranging white-tailed deer were collected on multiple pastures from 2 farms in north central Kansas between September 1997 and April 1998. *E. coli* O157:H7 was identified in 2.4% (5 of 212) of white-tailed deer fecal samples. |

| Citation | Findings/Comments |
|---|---|
| Schaife *et al.* 2006 | ***E. coli* O157**<br>Fecal samples from cows and rabbits (species not given) sharing range land in Norfolk, UK were collected in winter when there were few rabbits and in summer when there were many rabbits present. Samples were collected from 16 different cow herds. Researchers chose to examine cow / rabbit cohorts on 6 of the 7 farms on which fecal samples indicated that cows were shedding *E. coli* O157. Traps were set to catch rabbits, and fecal samples were collected from the trap area daily; traps were disinfected after each use. None of 32 rabbit fecal samples contained *E. coli* O157 in the winter sampling period. Two fecal samples on each of four farms contained *E. coli* O157 in the summer sampling period (total positives 8 of 97 (8.2%). One tagged rabbit was negative when sampled in the winter and positive when re-caught in the summer. |
| Shere *et al.* 1998 | ***E. coli* O157**<br>Researchers examined *E. coli* O157 content of the guts of necropsied wildlife on four Wisconsin dairy farms and sampled fresh dog feces as well. The samples were taken over a 14 month longitudinal study period. A total of 89 samples was collected from the following animals on the farms: deer, opossum, wild turkey, mice, rats, raccoon, birds (sparrows, starlings, pigeons), and flies. A total of 99 bird fecal samples were collected by cloacal swabs from pigeons, sparrows and starlings. Number of samples from each species not noted. One pigeon sample from a total of 99 bird samples (1%), and one fly trap was positive (authors state this as 5% of samples). In addition, one raccoon (*Procyon lotor*) sample was positive for *E. coli* O157. All other samples were negative. |
| Sprosten *et al.*, 2006 | ***E. coli* O157**<br>Slugs were collected from sheep pasture where *E. coli* O157:H7 contamination from previous sheep grazing was known. A total of 474 slugs was collected, separated into 33 groups, and homogenized in a sterile blender. A slurry of the homogenized slugs was tested for *E. coli* O157:H7. One in 33 groups tested positive. Additional laboratory investigation demonstrated that slugs exposed to *E. coli* O157:H7 contaminated food source shed the pathogen in their feces. |
| Srikantiah *et al.* 2004 | ***Salmonella***<br>Following a marked increase in *Salmonella* Javiana incidence in Mississippi, researchers tested reptiles and amphibians commonly found in patient yards for *Salmonella*. A total of 21 amphibians were collected, all were either Southern cricket frog (*Acris gryllus gryllus*) or Fowler's toad (*Bufo woodhouse fowleri*). Eleven individuals of the following species of reptiles were collected: green anole (*Trachymes scripta elegans*), ground skink (*Skincella lateralis*), red-eared slider (*Trachymes scripta elegans*) and common musk turtle (*Sternotherus odoratus*). Number of each species was not given. *Salmonella* Javiana was not recovered from any of the animals nor their feces. *Salmonella* Newport was isolated from a single Fowler's toad. |
| Talley *et al.*, 2009 | ***E. coli* O157**<br>Filth flies (flies that have a stage of development in animal feces) in the families *Muscidae* and *Calliphoridae* were captured in leafy green fields in the Central Coast of California. Eleven of 18 (61%) of the flies captured tested positive tested for *E. coli* O157:H7. A follow-up lab study demonstrated that house flies confined on manure or agar containing *E. coli* O157:H7 were able to transfer the bacteria to spinach plants. A marker used to trace presence of the *E. coli* bacteria on spinach leaves on which flies had landed found 50-100% of the leaves contaminated. |

| Citation | Findings/Comments |
|---|---|
| **Wallace *et al.*, 1997** | ***E. coli* O157**<br>Researchers isolated *E. coli* O157 from wild birds (mainly gulls). Freshly voided fecal samples were collected at two sites in England, one being a landfill waste site and the other an intertidal zone. Birds were primarily herring gulls, black-headed gulls, and common gulls, crows, and jackdaws. 400 samples were collected from each site over 4 visits. 2.9% of samples from the intertidal site and 0.9% from the urban landfill tested positive for *E. coli* O157:H7. No information about the extent to which these two samples represent different populations of birds is given. Distance between the sample sites is not given, nor is the food on which each group of birds feeds mentioned. Age and conditions that might impact the survival of *E. coli* O157:H7 in fecal material are not noted. |
| **Wahlstrom *et al.*, 2003** | ***E. coli* O157, *Salmonella*, *Campylobacter***<br>791 samples were collected from Canada geese, roe deer, hares, moose, wild boar and seagulls in Sweden. Samples were collected from animals that had been hunted. *E. coli* O157 was not isolated from any of the samples. *Salmonella* species were isolated only from seagulls, of which 4% were estimated to be positive. Thermophilic *Campylobacter* species were commonly isolated from all the species except the deer. |

Growers and food safety auditors regularly find evidence of animal incursion in row crops (e.g., crop damage, tracks, or fecal material). However, controlled studies examining the frequency of incursion into row crops by these animals, and detailed information about how behavior in the crop might impact contamination processes (e.g., contact of animal or animal feces with harvested portion of crop) is not available from the existing literature. Without a better understanding of the contamination process it is not possible to define risk from these incursions. Currently, the crop in areas around evidence of incursion is not harvested. The area designated for exclusion varies widely, however, and may even result in an entire field being removed from fresh produce production for an extended period of time (Schmit 2006).

The foodborne illness outbreak investigations presented by Jay *et al.* (2007) and Cooley *et al.* (2007) explored whether feral pigs may be involved in processes of contamination. The text box below and Appendix K describe their work in detail. No other wildlife studies provide the level of detail regarding contamination sources and processes as Jay *et al.* and Cooley *et al.* for deer, amphibians, rodents, and birds – the wildlife identified by growers in the mail survey as sources of buyer of food safety professional concern.

Pathogen prevalence in amphibians and reptiles in particular is not well represented in the literature. What is known does not clearly indicate what risk these animals pose to food safety. For example, studies conducted in laboratory settings using levels of imposed contamination far greater than are likely to occur in field settings must be interpreted with great caution. Laboratory settings may not reflect what is likely or possible in field conditions. In a study of wild caught amphibians and reptiles in natural settings, no human pathogens were detected (Richards *et al.*, 2004). Reports of amphibians (typically frogs) found in fresh produce occur in the media (Sacks 2008), but to date no evidence indicate that these episodes represent a food safety risk.[14]

Detailed studies documenting risk from rodents are similarly limited. Extension specialists and growers confirm that several local rodents including ground squirrels, mice, voles and rats are present as pests in fresh produce crops

[14] Food quality issues may influence the marketability of a product, and consumer choice, but they do not necessarily present food safety risk.

(Salmon 2008). While rodents are capable of carrying various strains of *E. coli*, *Salmonella*, and other infectious bacteria (Clark, 1994), the number of animals tested in field studies has been limited (Hancock *et al.*, 1998; Cizek *et al.*, 1999). In one study *E. coli* O157:H7 was isolated from Norwegian rats (Cizek *et al.* 1999). Ongoing research in the Central Coast region (see text box and Appendix K) is collecting information to help assess the prevalence of *E. coli* O157:H7 in local wildlife populations, including rodents.

Compared to information regarding rodents and amphibians, a larger body of literature demonstrates that some birds may carry important pathogens, including several bird species occurring in the Central Coast region (e.g., Canada geese, European starling, seagulls). Authors of several published studies report samples that are often of unknown age at collection. When detected, prevalence varies widely but is typically very low (see Table 2). Many of the studies were done in settings in which birds fed in cattle yards or areas of concentrated human waste (e.g., dumps), which the authors note increases the incidence of contamination. In a study of wild birds in England, Hughes *et al.* (2009) determined that while the birds were unlikely to be a direct source of Shiga toxin producing *E. coli* (STEC) they provide a potential reservoir of genetic variations that increase virulence of the pathogen. They note that the birds' capacity to serve as reservoirs of the bacteria, coupled with their ability to transport the bacteria long distances, means that wild birds have the potential to influence the spread and evolution of STEC.

Aside from the 2006 *E.coli* outbreak traced to Central Coast spinach, research for this report identified two other investigations regarding pathogen outbreaks in fresh produce for which a subsequent investigation found the pathogen in animal fecal matter collected on the implicated farm. In a recent investigation of a *campylobacteriosis* outbreak linked to fresh peas in Alaska, the strain of the bacteria that made people ill was isolated from Sandhill crane feces found in the field from which the implicated produce was harvested (Gardner and McLaughlin 2008). *Campylobacteriosis* is caused by bacteria in the genus *Campylobactor*, and causes gastrointestinal symptoms that may be quite severe. In the Alaska outbreak, an estimated 99 people who ate the peas became ill from *campylobacteriosis*, five of whom were temporarily hospitalized (none died). The other investigation involved a *Yersinia pseudotuberculosis* outbreak in carrots in Finland. This pathogen causes illness accompanied by fever and severe abdominal pain that mimics appendicitis. The outbreak bacterium was isolated from a pooled sample of common shrew (*Sorex araneus*) intestines from one farm (Kangas *et al.* 2008). As with the 2006 E.coli O157:H7 outbreak in spinach in the Central Coast region, the process of contamination in the pea crop in Alaska and the carrot crop in Finland is not well described.

Deer have received much discussion as hosts of pathogens, in particular of *E. coli* O157:H7. Some (but not all) studies have shown deer to contain pathogens (see Table 2). Additional discussion of pathogens in deer appears below, particularly when they share range land with cattle.

**Investigation of Contamination Processes**

Following the 2006 *E. coli* O157:H7 outbreak in bagged spinach, intense research focus centered on the area from which the product was harvested. The research was unique in its effort to detect evidence of the pathogen in a wide range of sources, not just a specific animal (in this case feral pigs), and in its effort to capture important information about how contamination processes involving wildlife and cattle may occur. The study sampled water, soil, and wild and domestic animal feces for *E. coli* O157:H7 (Jay et al. 2007). Combined with work by Cooley et al. (2007), which traced potential fate and transport of *E. coli* O157:H7 with a source tracking method in the same samples, the research provided the most comprehensive and relevant data available to address the role of feral pigs in *E. coli* O157:H7 outbreaks in fresh produce.

In both studies the authors conclude that feral pigs are among the potential sources or vectors of *E. coli* O157:H7, but that the process by which the produce was contaminated remains unclear. The influence of the high population density of feral pigs and proximity to cattle on prevalence of *E. coli* O157:H7 were identified as important areas that need further research. Jay and Wiscomb (2008) subsequently published a review of food safety risks and mitigation strategies for feral swine near agriculture fields that highlights the best known practices at this time.

For additional information about this research see Appendix I.

***Risk from Cattle:*** Studies relevant to pathogen risk in wildlife note the prevalence of pathogens in domestic animals. Domestic ruminants are documented sources of *E. coli* O157:H7 (Pedersen and Clark, 2007). Studies demonstrating high pathogen prevalence in cattle typically examined prevalence in Concentrated Animal Feeding Operations (CAFOs) or large dairy production systems. Neither of these types of operations have a significant presence in the Central Coast region compared with ranch-based, cow-calf operations. That said, it is worth noting that the specific *E. coli* strain that caused the 2006 spinach outbreak was found in pastured "grass fed" cattle on the ranch where the spinach was grown (California Food Emergency Response Team 2007; Jay *et al.*, 2007). Most cattle in the region are pastured beef cattle. See Table 2 and Appendix I for citations and details regarding pathogen prevalence in cattle and local cattle production information. Cattle are by far the largest domestic animal presence in the region, however small numbers of sheep and goats are also present and may pose some risk.

Although neither CAFO's nor dairy operations are a large component of Central Coast cattle operations, connections to large dairy operations and CAFO's outside the Central Coast region exist. These connections exist through use of composted manure products as soil amendments in row crops, and through the periodic rotation of stocker cattle from outside the area to Central Coast winter range land. No studies have examined direct links from these products or practices to crop contamination. Raw manure is not applied to fresh produce production areas, and compost manufacturers manage the composting conditions (temperature, moisture, aeration, duration) to effectively mitigate pathogen risks before finished product is sold. Strict processing guidelines (See Appendix I) ensure that pathogen contamination risk is minimized, but it may not be completely eliminated.

Growers receive verification of composting methods with each shipment of composted material to document use of approved methods. Nonetheless, as noted above, growers report reduced use of compost and manure,[15] as well as reduced cattle rotation on cropland in response to food safety concerns.

Because processes of contamination remain unclear, one cannot rule out the possibility that local cattle may be involved in pathogen contamination of fresh produce. Central Coast cattle often graze on lands near or adjacent to row crop production, typically on hillsides from which seasonal run-off may move to fresh produce production areas.[16] Both fresh produce growers and cattle managers acknowledge the risk inherent in this arrangement, and have developed management guidelines to minimize the risk of either waste materials, or water which has come in contact with waste materials, reaching produce fields or irrigation reservoirs. Appendix I contains an excerpt from a document produced by Central Coast Cattlemen describing a wide variety of management practices suggested to minimize contamination risk, including maintenance of adequate vegetative cover and strategies to direct cattle movement away from crop production areas. The extent to which ranchers follow these guidelines is unknown at this point. Growers attempt to protect water sources and produce from animal intrusion or run off from range land by maintaining separation between rangeland and crops and water sources, by fencing, and by avoiding planting in areas that cannot be adequately protected.

***Risk from Deer Sharing Range Land with Cattle:*** Several studies have investigated pathogen prevalence in deer and cattle that share range land (Branham *et al.* 2005; Fischer *et al.* 2001; Sargeant *et al.* 1999). When researchers sample cattle and deer from the same area, infection rates in deer (when researchers document infection) are not as high as those found in cattle. None of the studies examining pathogens in deer and cattle sharing range land have been done in California. Pathogen movement between domestic and wild animals may depend on pathogen persistence in the shared environment, and other factors dependent upon local conditions. Thus, research to verify that similar results are found when research is repeated in a variety of locations, including the Central Coast produce growing region, is essential. Ongoing research is addressing this information gap. At this point, an understanding of how pathogens may transfer from domestic to wild animals (or the reverse) is incomplete.

***Research Questions:*** Evidence exists that cattle, deer, wild pigs and some birds are capable of carrying pathogens and shedding them in waste products. A lack of sufficient information regarding the prevalence of pathogens in wild amphibians and rodents makes assessment of the risk presented by these animals impossible at this time. There is very limited data for other animals that may enter crop land, including dogs, coyotes, possums, raccoons, cats, bobcats, and rabbits, among others. Research conducted in the Central Coast region and guided by the following questions is essential to inform food safety guidelines:

1. What pathogens are found in each type of animal of organism? With what frequency?
2. Are wildlife species significant sources and/or vectors for important pathogens?
3. What types of animals live in the farm environment? Do they enter crop fields or remain in adjacent areas?
4. Do specific features, such as vegetation or water sources, encourage wildlife to enter ranches and farms?

---

[15] LGMA food safety standards does not allow the use of raw manure on fresh produce crops (Leafy Green Handler Marketing Board 2008).

[16] Runoff from rangeland is only likely if it is irrigated, or during seasons in which there is rainfall. The majority of the rainfall in the region is received between October and April, yet pathogen contamination events are most frequent in the late summer and early fall. Movement of pathogens in runoff from rangeland may be significantly reduced when there is vegetation present, as is typical in rangeland (Tate et al., 2006).

5. Is it necessary for the animal to move into the crop field to contaminate produce, or is it possible to facilitate contamination without direct contact? For example, do pathogens from fecal materials or other contamination sources reach crop fields via water, wind, or attached to other materials or organisms?

6. How do animal species known to carry pathogens become infected (e.g., by eating cattle manure or drinking contaminated water)?

***Risks from Non-crop Vegetation:*** Two assumptions seem to underlie food safety concerns related to non-crop vegetation: first, that wildlife are attracted to these plantings; and second, that wildlife and their wastes in proximity to crops are a risk to food safety. Risk from wildlife is discussed above; the review below focuses on what is known about how non-crop vegetation attracts wildlife, and the extent to which wildlife moves from non-crop vegetation to crops.

Expert opinion from wildlife biologists and conservation agency staff suggest that certain wildlife are attracted to habitats created by non-crop vegetation, and that others (such as feral pigs) are more mobile and less likely to be attracted to such areas. Jay and Wiscomb (2008) note that habitat removal is not likely to be an effective control strategy for feral swine, due to their mobility and large home range. Salmon (2008) notes that rodents naturally occur in range land and other vegetated areas, and that it is reasonable to assume they will at least occasionally enter crop production areas if they are nearby. Animals may move into or through crop land to reach food or water sources or wildlife movement corridors even if they do not feed on the crop.

Earnshaw (2003) notes that some grass plants produce less seed than others, and therefore tend to attract fewer mice. Management parameters may also influence the extent to which animals are attracted to non-crop vegetation. For example, the NRCS and Monterey County RCD advise that mowing vegetation used in grassed waterways and filter of buffer strips may reduce wildlife presence by reducing cover provided by the vegetation.

Aside from flies,[17] insects have not been a focus of food safety research. Because much of the research on species attracted to non-crop vegetation has focused on insects as pollinators, pests, and the natural enemies of insect pests, these studies provide little insight into food safety concerns. Aside from sporadic anecdotal information, there is little or no information that describes the species attracted to various non-crop vegetation practices, nor about the movement of these species in crop fields.

***Research Questions:*** Information regarding wildlife use of non-crop vegetation is generally not from controlled or systematic studies. Rather, it is information shared informally among growers or conservation agency staff, and is occasionally included as observations in manuals intended to guide implementation and management of various non-crop vegetation systems. Evidence exists that wildlife species, including insects, differ in the extent to which they are attracted to or use non-crop vegetation. Collaborative efforts to combine information from expert experiences, combined with research efforts in the Central Coast region and guided by the following questions is essential to inform food safety guidelines:

1. What are the patterns of use and movement with wildlife species into and through non-crop vegetation adjacent to croplands.

2. To what extent are insect species potential vectors of pathogens?

[17] See Appendix H for additional information about flies.

3. Would increased information about species' preference for vegetation allow management of non-crop areas to reduce the incidence of particular wildlife species of concern?

4. What additional farm management practices, like mowing of filter strips to reduce cover for rodents, might reduce preference for particular wildlife species?

***Risks from Water Bodies:*** The same two assumptions regarding the food safety risk posed by non-crop vegetation also underlie concerns relevant to water bodies in the production area – namely that these areas may attract wildlife and that wildlife and their wastes pose a risk. The latter is discussed above. As noted above, cattle may be important pathogen sources; however, these animals' access to water bodies in production areas is typically controlled by intentional placement of water supplies and fencing. Use of cattle, goats or sheep to graze crop residue on harvested crop land, a valuable nutrient cycling strategy, is no longer commonly practiced in fresh produce production areas. To the extent that domestic animals are in close proximity to crops or irrigation water sources (e.g., via a broken fence), domestic animals' movement around water bodies near crop areas is also of interest.

In areas where water is scarce, which is the case for much of the dry season (approximately May through November in the Central Coast region), animals may seek water sources in farming areas. Fencing around water bodies that are intended for irrigation use is common to exclude animals both for practical and food safety risk concerns. In water systems that are more extensive and may be more difficult to fence (e.g., natural water features or a large constructed wetland) it is more likely that a variety of animals will be attracted. Amphibians, birds, and rodents may be among the more challenging to exclude because of the larger numbers of these animals, and the ease with which they may pass a barrier fence. As noted above, how, or if, these animals may contribute to processes of contamination is poorly understood. Currently, there are no known studies demonstrating that wild amphibians pose a food safety risk.

California red-legged frogs (*Rana draytonii*) and California tiger salamanders (*Ambystoma californiense*) – federally protected species for which the Central Coast contains critical recovery habitat – rely upon ponds in range land areas (Symonds 2008). Since both red-legged frogs and tiger salamanders are thought to disperse 2-3 km from their natal ponds, movement into farm ponds near range land is a reasonable assumption. Red-legged frogs are more likely to be found in areas in which suitable terrestrial habitat occurs within 100 meters of a frog-occupied water source (Bulger *et al.*, 2003). Red-legged frogs have been documented in and near row crop areas in the Central Coast region (Bulger *et al.*, 2003; Seymour and Westphal, 2000; Westphal and Seymour, 1998) and also have been known to migrate across agricultural land (Bulger *et al.*, 2003).

Wildlife is likely to be attracted to water sources wherever they occur in the landscape. Field surveys find that non-native bullfrog (*Lithobates catesbeiana*), as well as the native Pacific chorus frog (*Pseudacris regilla*) and western toads (*Anaxyrus boreas halophilus*), are commonly found in or near on-farm water bodies. In a survey of an irrigation reservoir in San Mateo County western yellow-bellied racer (*Coluber constrictor mormon*), coast garter snake (*Thamnophis elegans terrestris*), Pacific chorus frog, California red-legged frog, and rough-skinned newt (*Taricha granulosa*) were all found (Swaim Biological, Inc. 2007). The presence of both adult red-legged frogs and metamorphs (young frogs recently developed from tadpoles) in and around irrigation reservoirs in San Mateo, Santa Cruz and Monterey County suggests that these water bodies are important habitat for red-legged frogs in the region (Bulger et al., 2003; D'Amore *et al.*, 2009; Smith, 2002; Swaim Biological, Inc.; Westphal and Seymour, 1998; Seymour *et al.*, 2007). The importance of farm water sources as wildlife habitat has increased as natural wetlands have declined (Noss *et al.* 2001). A number of state and federal programs encourage enhancement of on-farm water bodies for wildlife habitat (Wolinsky, 2005).

The sensitive western pond turtle (*Actinemys marmorata*) and San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) are rarely found in on-farm ponds, though many local and migrating species of birds have been observed in on-farm water bodies (Rich Seymour, personal communication).

***Research Questions:*** As with non-crop vegetation, information regarding wildlife use of water bodies is generally not from controlled or systematic study. Evidence exists that wildlife species, particularly in the dry summer and fall months, use water bodies in or adjacent to crop production areas. Collaborative efforts to combine information from experts' observations, combined with research efforts in the Central Coast region and guided by the following questions are essential to inform food safety guidelines:

1. Which animals are attracted to water?

2. What strategies are useful to exclude wildlife if they are a food safety risk?

3. Is it possible to selectively exclude wildlife so that species that do not present food safety risk may still access water supplies?

***Summary of Risk Evaluation:*** Growers report being told that wildlife, domesticated animals, non-crop vegetation and water bodies present food safety risks in their crop production areas. However, sufficient information to fully define and effectively manage these risks is lacking. For example, the majority of the available literature regarding pathogen presence in wildlife was conducted outside of California, and before the development of improved detection methodologies. As noted, pathogen movement and persistence, and other factors dependent upon local conditions, may vary by geographical region. Thus, caution is required when applying results of research from outside the region to local settings.

Some studies have demonstrated pathogen presence or vectoring potential in diverse wildlife species, generally at low frequencies. Three investigations following illness outbreaks have found the same pathogens that made people sick in samples of feces (cattle, feral pigs, cranes), intestinal samples (shrews), and water collected near fields where the implicated produce was grown. No investigations have linked frogs collected near fields to outbreaks of food-borne illness. While studies with cattle in confined animal operations have found high levels of pathogens, such operations are not typically found on the Central Coast.

The existing body of research contains little information about the potential for (or relative importance of) direct contamination (e.g., contaminated feces coming into contact with fresh produce), or indirect contamination of the growing environment (e.g., contamination of water, soil, dust, or bioaerosols) by domesticated animals and wildlife. The current level of understanding is not sufficient to fully predict risk posed by various contamination sources and processes. Much of the research to date has helped answer the question, what *can* happen with regard to pathogens in wildlife and domestic animals? Focus has largely centered on the fact that some species of wildlife *can* carry pathogens, and that they enter crop fields. To fully assess the risks posed by these animals it is necessary to answer the questions: what *does* happen, how much risk does it pose, and what can be done to minimize risk?

It is beyond the scope of this report to consider all the factors likely to contribute to contamination processes. Because wildlife featured prominently in investigations of a high profile outbreak linked to fresh produce from the Central Coast region, and because growers report taking actions to reduce wildlife for food safety reasons, this report focuses on wildlife and food safety risks. Several other potential sources of farm-based contamination exist, including domesticated animals, water, soil amendments, and workers (see LGMA 2008), all of which are subjects of ongoing research and extensive farm-based food safety practices that lie beyond the scope of this report. Persistence of pathogens in the environment (in soil and water and on crops), mechanisms of transfer from waste material or contaminated water to crops, and the role of soil management and environmental factors in pathogen survival are among other important variables that also influence contamination processes. Several overviews of this topic are available and the reader is encouraged to consult these (e.g., , Brandl 2006, Doyle and Erickson 2008, Harris *et al.* 2006, Suslow 2003).

### C. What Evidence Demonstrates Impact of Management Practices?

As described above, growers report several on-farm management strategies adopted in response to food safety concerns. These responses can be characterized as follows:

- Deter or eliminate wildlife;
- Reduce non-crop vegetation (either by removal or by reduced use);
- Reduced construction, discontinued use, or removal of non-natural water bodies;
- Destruction of natural water bodies by draining or filling.

It is important to note that the RCD survey results only partially quantify the changes in management practices used to address food safety concerns. Survey data do not provide specific details of changes to management practices. For example growers report use of **bare ground buffers**, but details of placement and what the **bare ground buffer** replaced are not known. Fully evaluating impacts of management practice changes would require defining details of implementation in the field, which is beyond the scope of this report. The following, therefore, summarizes what is known about how changes in management practices to achieve improved food safety can impact ecological health, and also the *likely* impact of the changes on both ecological health and food safety.

***Deter or eliminate wildlife:*** Actions or specific practices reported by growers that are taken to reduce movement of wild animals near fresh produce production areas include fencing, installing **bare ground buffers**, trapping, use of poison bait, use of copper sulfate, and hunting and shooting.

<u>Fencing</u>: Foraging (for both food and water), mating behavior, seasonal movement or migrations, and shelter needs are all important factors in how wild animal populations can be sustained within a landscape. Fences may interfere with animals' ability to access important resources. Atwill (2008) reports that much of the riparian corridor along the Salinas River is now fenced, and that the remaining gaps in fencing have high concentrations of wildlife transiting them. In the case of fencing along riparian corridors, escape from flood waters may also be problematic (Paige, 2008).

Neither of the two grower surveys (2007 & 2009) provides specific information about precisely where fencing is erected, how extensive its use is, and the extent to which fences disrupt typical animal movement. Fencing designs range from four-foot-tall black fabric fencing with soil used to seal the lower boundary to chain link fences of heights up to 10 feet, and include a number of other options. Some animals are notoriously difficult to deter (e.g., feral pigs) as they are able to destroy fences or dig around or under them. Jay *et al.* (2007) found that wild pigs could pass under a fence due to erosion and rooting (animal digging). Red-legged frogs have also been found able to climb over frog barriers, though not consistently (Rathbun *et al.*, 1997)

It is broadly accepted in the field of ecology that isolated remnants of habitat suffer predictable, cumulative losses of species (Soulé, 2001). In the California context, habitat fragmentation was described in a California-wide analysis of wildlife corridors and landscape connectivity (Penrod *et al.*, 2001). The report describes over 20 threats to animal movement and habitat connectivity; the top three being urbanization, roads and agriculture. Based on this report, the impact of additional fencing around and on agricultural lands is practically certain to further reduce connectivity among remaining natural areas and adversely affect local wildlife.

Bare ground buffers: Installing bare ground buffers serves two purposes. First, they allow inspectors and growers to see tracks or other evidence of animal incursion into crop fields. Second, they are assumed to reduce animal movement by providing a vulnerable area that small animals are less likely to cross (e.g., no vegetation cover in which to hide from predators). Creating open ground may decrease movement of some but not all rodent pests (Salmon 2008). The width required for bare ground buffers to be effective in discouraging movement of rodent pests into crop fields is unknown (Clarke, 1995). The impact of these buffers depends upon how much area is affected, the species likely to move in those areas, and whether or not creation of the buffer entails removing non-crop vegetation, all of which are site specific. For all these reasons, it is not possible to describe the effect of these buffers on wildlife at this time.

Trapping and Use of Poisoned Bait: Trapping and poison bait use are practices aimed at defining rodent populations (trapping) and reducing them (trapping and use of poison bait). Growers have long used poisons to control rodent populations as a standard management practice unrelated to food safety concerns (Salmon, 2008). The University of California and the California Department of Pesticide Regulation both maintain statewide pesticide usage statistics that document widespread and long-term use of specific pesticides in Central Coast counties, including a wide variety of **anticoagulants.**[18] Documented **anticoagulant** use in the study area includes "first-generation" rodenticides (warfarin, chlorophacinone, diphacinone) and a more lethal set of "second-generation" rodenticides (brodifacoum, bromadiolone, difenacoum, and difethialone).

Rodenticides are generally placed in T-shaped PVC pipes in an attempt to minimize consumption by non-target animals, however there is little clear knowledge about which rodent species take the poison (Salmon 2008). The 2007 grower survey found that poison baits were the most commonly adopted wildlife mitigation measure (RCD 2007). As noted in Salmon (2008) and documented during field visits conducted during research for this report, it is common to see leafy-green field borders lined with PVC bait stations most likely containing first-generation **anticoagulant** materials. As the marketing director for a major lettuce buyer noted, "Some processors are requiring trapping stations [bait stations] every 50 feet for rodents" (Salmon 2008).[19]

A concern investigated during research for this report was that increased poison bait use in response to food safety concerns may decrease mice, vole, and other rodent populations so dramatically that raptors and other predators could face a reduced food supply. A California Department of Fish and Game biologist interviewed for this report commented that starvation risk to raptors is small given their low population densities on the Central Coast region, and their ability to migrate to areas with more abundant prey.

However, other concerns remain. After more than a decade of research and an intensive public comment process, the U.S. Environmental Protection Agency recently concluded that **anticoagulant** rodenticides pose a significant risk to both human health and the environment (U.S. EPA 2008a). With respect to wildlife, EPA notes:

---

[18] For University of California data, see http://www.ipm.ucdavis.edu/PUSE/puse1.html. For California Department of Pesticide Regulation data, see: http://www.cdpr.ca.gov/docs/pur/purmain.htm

[19] Rodenticide use may be less widespread than the abundance of visible T-shaped stations suggests. Growers report that food safety inspectors are now requesting less use of these poisons because they increase risk of dead or poisoned animals in crops.

*"EPA's comparative ecological risk assessment concludes that each of the rodenticide active ingredients poses significant risks to non-target wildlife when applied as grain-based bait products. The risks to wildlife are from primary exposure (direct consumption of rodenticide bait) for all compounds and secondary exposure (consumption of prey by predators or scavengers with rodenticide stored in body tissues) from the anticoagulants."* (US EPA 2008a, p.7)

Drawing mostly from New York and California data, U.S. EPA has documented more than 500 incidents nationwide of dead mammals and birds testing positive for **anticoagulants** in liver tissue, representing 44 species (U.S. EPA 2006). **Anticoagulant** incidents are based on detection of residues in liver tissue and corroborating evidence from carcass necropsy. Although tissue analysis showed that second generation **anticoagulants** were present in most cases, numerous mortality incidents also occurred where the dead animal only contained first generation **anticoagulants**. According to U.S. EPA (2006), avian species in this category included hawks, owls, turkeys, falcons, and a bald eagle. Mammalian species included coyotes, bobcats, mountain lions, raccoons, deer, squirrels, badgers, and the federally endangered San Joaquin Kit Fox. Within California, 71% of liver samples from 35 dead mountain lions contained at least one **anticoagulant** rodenticide. Eighty-four percent (84%) of 32 dead San Joaquin kit foxes also tested positive, as did 79% of 39 dead bobcats (U.S. EPA 2006).

The adverse impacts of anti-coagulants on non-target species and through **bioaccumulation** are well documented, and are reasonably assumed risks related to use of these poisons. Pesticide use statistics provide some insight, but the magnitude of the impact of poisoned bait on non-target species remains poorly defined.

**Use of Copper Sulfate**: Use of the algaecide **copper sulfate** to maintain irrigation reservoirs (engineered water bodies, specifically managed for irrigation use) clear of algae so that irrigation equipment is not damaged or disabled is a widespread and accepted agricultural practice in the Central Coast region[20]. **Copper sulfate** is labeled for use to minimize growth of algae and aquatic weeds in ponds, and for use in flooded rice fields to control freshwater snails, leeches, and tadpole shrimp. Irrigation reservoirs are not intended for use as habitat, and are not typically maintained to encourage wildlife presence; thus, in theory at least, fewer animals are likely to be present or affected. Nonetheless, as discussed above, field surveys document that many animals do use these water bodies.

A small number of survey respondents report use of this material to reduce frog and fish populations in irrigation reservoirs, and to control frogs in other water bodies. Several growers interviewed for this project specifically explained that they have increased **copper sulfate** use to reduce frog populations in response to food safety concerns expressed by auditors or others.

Copper toxicity in fish and aquatic invertebrates is caused by interference with the ability of gills to function properly (U.S. EPA, 2008b). A recent study by Garcia-Munoz et al. (2009) found toad tadpoles exposed to **copper sulfate** showed reduced growth and decreased escape behavior, both of which may reduce survival. Chen et al. (2007) found similar results in leopard frog tadpoles exposed to **copper sulfate**. Copper in sediments may have adverse impacts on midge larva (Servia et al. 2006), suggesting that cumulative effects of copper sulfate application may be of importance for some species. The above studies were done in laboratory conditions, and indicate the need to investigate the effects of copper sulfate in field conditions. **Copper sulfate** tends to rapidly immobilize in sediments, probably in association with organic fractions (van Hullebusch et al., 2003), and behavior in a natural system may be quite different from that of laboratory observation.

[20] Increased use of irrigation systems that are easily disabled by algae (e.g., drip irrigation) may lead to increased use of this material in the region.

The federally protected California red-legged frogs and California tiger salamanders each have a life stage as gill-breathing organisms. The above research strongly suggests that impact of **copper sulfate** on these populations is possible when exposure occurs. As noted above, it is likely these species use farm ponds at least in some settings. More information is needed to assess the impact of **copper sulfate** on wildlife in field settings with typical **copper sulfate** application rates.

Hunting and Shooting: Growers report hunting and shooting of wildlife to reduce animals perceived to pose a food safety risk. Feral pigs and deer are both large game legally hunted in California and among the animals targeted by food safety-related hunting. Boxall (2009) notes that following the 2006 *E. coli* O157:H7 outbreak, an increase in requests for state depredation permits occurred, which allow farmers to shoot some wildlife species that damage their crops.

Waithman *et al.* (1999) report that feral pig populations can withstand an annual combined mortality rate (death by all causes) of 70% without affecting existing populations. It should be noted that feral pigs are non-native species, and as such the relative merits of concerns of hunting them should consider their impact not just on agriculture and food safety risk, but also on broader ecosystem balance (Kreith, 2007). Deer are managed by the California Department of Fish and Game to maintain populations for both ecological balance and big game hunting. Historically their populations have fluctuated, largely in response to available habitat (DFG, 2009). The impact of increased hunting by growers with depredation permits is not documented.

Species other than deer or feral pigs may be targeted by growers concerned about wildlife presence, but there is little information to document such hunting. Determining whether hunting occurs, and the extent of it, would be necessary to fully understand the impact of hunting on wildlife populations.

**Reduce non-crop vegetation:** Actions reported by growers that reflect reduced use of non-crop vegetation include creation of **bare ground buffers**, removal of vegetation intended to reduce run off and erosion, removal of vegetation from farm ponds and ditches, removal of trees and shrubs, and removal of wetland or riparian vegetation. A comprehensive discussion of all research relevant to the use of non-crop vegetation in on-farm management strategies is beyond the scope of this report. Appendix J provides background information to document the benefits of non-crop vegetation to soil and water quality and protection, as well as to support sustainable farming practices, such as integrated pest management. Research relevant to the effectiveness of non-crop vegetation as a conservation management strategy in irrigated row crops in Central Coast region settings is included below.

**Bare Ground Buffers** or Removal of Vegetation Intended to Reduce Run Off and Erosion: Soil without vegetative cover is susceptible to increased erosion by wind and water, and also tends to develop poor surface structure, thereby decreasing water infiltration and increasing surface run off. The impact of bare ground on soil and water quality depends in large measure on topography and the land use it replaces (e.g., vegetated buffers or waterways, hedgerows or field margin plantings, crop acreage, riparian vegetation).

By slowing surface water movement and capturing suspended soil and debris, vegetated buffers may retain and break down pollutants, decrease erosion, increase soil deposition, increase nutrient uptake by plants, and increase microbial activity. Vegetated buffer zones have been found to effectively remove some pesticides from surface run off. Vegetated buffers and filter strips have also been shown to reduce the transfer of pathogenic bacteria in surface water. See Appendix J for citations and details of relevant studies to support these statements. This ability may be particularly important in the Central Coast region between range land and crop land. Pathogen movement by overland flow from range lands may be reduced when perennial forage and/or grasses act as a barrier to reduce movement of manure and water downslope (Tate *et al.* 2006). In rangeland systems, manure deposition is typically spread across a wide area, and water flow is typically not concentrated. The benefits relate to both mechanical trapping of manure, and increased infiltration of water as it moves across the landscape.

To assess the impact of **bare ground buffers** and un-vegetated areas on both food safety and ecological health, it is essential to know how extensively they are used, and where they are placed in the landscape (e.g., upslope from cropland to protect from adjacent land use run-off or downslope from cropland to filter irrigation run-off). Of particular importance is information regarding proximity to sensitive areas (e.g., water bodies or crops), and whether vegetation exists between sensitive areas and **bare ground buffers**. Slope, volume and concentration of run-off, and soil type and structure are also important factors.

Other management practices may be available to mitigate the water quality impact of **bare ground buffers** downslope from cropland. Increased use of drip irrigation, as well as other irrigation management practices that reduce water use and/or irrigation water runoff[21], decreases the volume of water moving across or off of cropland. Vegetated systems downslope of the field may then be effective in reducing movement of pollutants and contaminants. Drip irrigation may also help minimize pathogen contamination risk. Soloman *et al.* (2002) found greater numbers of plants tested positive for *E. coli* O157:H7 when irrigated by sprinkler irrigation than when irrigated by drip irrigation. Fertigation (application of fertilizer through the irrigation system) in drip irrigation systems reduces nutrient loads in run off or tail water as nutrients are more precisely placed to reduce application rates. Applications of materials still being developed may decrease soil loss by holding fine soil particles together in larger aggregates (e.g., **PAM**) or reduce organophosphate pesticide contamination of tail water with an enzymatic treatment that helps break down organophosphate pesticides (e.g., **Landguard®**).

In places where range land abuts crop land, and where bare ground allows increased flow of upland run off to reach crops or irrigation water sources, **bare ground buffers** have the potential to reduce not just ecological health, but food safety as well. Because bare ground buffers do not capture debris that may carry contaminants, nor facilitate infiltration of surface runoff as effectively as vegetated buffers, movement of pathogens through them is more likely.

Removing vegetation from farm ponds and ditches: Intentionally vegetated ponds – also called Vegetated Treatment Systems (VTS) – are constructed to hold or convey runoff and/or tail water and to facilitate contaminant retention, sorption, and breakdown. Vegetated treatment systems may reduce runoff, sediment delivery, and nutrient (nitrogen and phosphorus) and pesticide content of discharge water. Vegetation within waterways can also reduce the presence of water borne pathogens. Appendix J provides detailed information and citations to support these statements.

Effective vegetated ditches (also called Grassed Waterways) are constructed to convey run-off without causing channel erosion and thereby prevent additional sediment from being transported downstream to waterways. To reduce nutrient or pesticide content effectively, the vegetated ditch must be installed with a broad flat bottom, with minimal slope and limited runoff volume.

Hunt *et al.* (2007, 2008) measured the effectiveness of two vegetated pond systems in reducing concentrations of both pesticides and nutrients. Both ponds were originally constructed to retain sediment and had been maintained since with vegetation established to help increase denitrification (a process by which excess nitrogen in water is reduced) and microbial populations (to facilitate pesticide breakdown), and to slow flow through rates (to increase sedimentation). Both water and sediment concentrations of pesticides were lower at the outlets of both VTS than at the inlet, demonstrating the ability of both systems to effectively reduce pesticide loads from farm runoff. Turbidity

[21] An alternative irrigation strategy that reduces run-off from overhead sprinklers is to use "hand-move" lines so that the field is irrigated in several sets. Compared to solid-set sprinklers, where fields are irrigated in a single set, the overall application rate of hand-move sprinklers is lower.

(a measure of sediment load) and nutrient levels were consistently lower at the outlet of one VTS, but not the other. The effectiveness of the VTS to retain pesticides carried in farm run off appears to vary, and is dependent upon the manner in which individual pesticides interact with sediment as they are retained, residence time, effective contact with vegetation and other factors in each VTS.

Anderson *et al.* (2008) built upon the work of Hunt *et al.* (2007, 2008) and demonstrated that a vegetated ditch system was effective at reducing pesticide concentrations, especially when used in conjunction with **Landguard®** treatment. While some pesticides (organochlorines and pyrethroids) showed declines after treatment in the sedimentation and vegetated sections of the ditch, diazinon (an organophosphate) was not sufficiently removed during the VTS residence times observed in the study. **Landguard®** was able to effectively remove diazinon.

**Factors that influence practice effectiveness:
The case of vegetation**

Research conducted in irrigated row crops in the Central Coast region suggests that the effectiveness of VTS and vegetated ditches can vary based on site specific characteristics, and the design and maintenance of the practice. The value of vegetation as described above is best demonstrated in systems receiving low volume of water with low levels of pollutants and contaminants, such as water flowing off of range land (e.g., Tate *et al.* 2006). The impact is less evident in typical narrow V-shaped ditches and treatment ponds receiving high volumes of water with high levels of pollutants and contaminants. Cahn et al. (2009) found that VTS and vegetated ditches were not consistently capable of reducing the concentration of suspended sediments and nutrients in water, nor coliform and *E. coli* bacteria, in the run off from research trials in irrigated vegetable crops in the Central Coast region. Supporting practices, appropriate design, residence time (the amount of time water remains in the VTS), contaminant load, turbidity (amount of suspended solids), and contact with vegetation all influence the effectiveness of VTS. Overall, the research provides a reminder that efficacy of conservation practices varies widely. The impact of removing them is dependent upon how effectively they were installed and managed.

In addition to uncertainty regarding the ability of VTS to handle the volume of water and contaminants typically discharged from irrigated row crops (particularly those without tile drainage[22]), difficulty in maintaining these practices may reduce their effectiveness. Local soils vary in texture and structure, with some being more challenging for establishment of effective VTS than others. Visits to farms in the area revealed an instance where water flowed around the vegetation in a VTS, making little contact with it. In such cases, the effectiveness of the system is compromised. Growers and UC Cooperative Extension personnel recount difficulty in maintaining VTS in optimum conditions, and effectiveness of VTS undergoes continuous assessment by growers, extension personnel and research scientists.

Given the persistent problems with excess nutrients, sediment and pesticides in agricultural runoff in the region, suites of conservation practices used in tandem are appropriate. While VTS may not be universally or solely effective, both the extensive body of literature and local research suggest they are an important component of water quality

[22] Tiled drainage systems are generally installed in soils with poor drainage. Without installation of such drainage, fields are prone to waterlogging. Less water tends to be discharged from such systems, and any water discharged has already passed through the soil, a potent filtration system that significantly reduces sediment and pesticide loads, though not necessarily nutrients.

management. Since their level of effectiveness varies based on site-specific characteristics, proper design and maintenance, it is difficult to know precisely how reduced use of these systems may impact water quality. However, where they have been found to be effective at reducing pollutant transport downstream, their loss is practically certain to reverse water quality gains at the farm level.

Removing trees and shrubs: Trees and shrubs in the agricultural landscape may be present as hedgerows, windbreaks, wood lots, field border plantings, and stands of native vegetation, especially along streams or rivers. According to USDA Natural Resources Conservation Service standards (NRCS 2002), hedgerows may serve as living fences, provide food and habitat for wildlife, create barriers for pesticide drift, dust and odors, and improve the landscape appearance. These plantings may provide habitat for predator and pollinator insect populations (Denys and Tscharntke 2001, Earnshaw 2003, Kremen *et al.* 2002, Pickett and Bugg 1998), and reduce pest populations and displace noxious weeds (Ehler *et al.* 2002, Long and Pease 2005).[23]

Landscape connectivity is required to maintain wildlife populations that are well balanced in both numbers and composition (e.g. predators and prey) (Soulé, 2001). Corridors of vegetation connecting areas of habitat can provide critical connectivity and serve as "stepping stone reserves" for insects, pollinators, seed dispersers, bats, birds, and other species (Penrod *et al.* 2001; Rosenberg and Noon 1997). Use of tree patches has been demonstrated to be important for red-legged frog populations, which move away from water sources in the non-breeding season (Chan-McCleod and Moy, 2007).

Vegetation loss plays a role in landscape-level habitat fragmentation, which persists as the most widespread and pernicious threat to wildlife worldwide (e.g., Millenium Ecosystem Assessment 2005, Groom *et al.* 2006). In a conference in which participants identified 20 key wildlife corridors, gaps in habitat cover is listed as a primary barrier to animal movement in 35% of the corridors identified in the Central Coast region (Penrod *et al.*, 2001).

Hedgerows and other stands of trees or shrubs can have a beneficial effect of reducing wind velocities in their vicinity. Dispersal of pathogens with dust has been documented (Chang *et al.*, 2001, Lee *et al.*, 2006, Whyte *et al.* 2001). If a pathogen capable of dispersal by dust and wind is present near a crop field, the removal of hedgerows or other vegetation that reduce dust on crops may compromise not only crop quality, but also food safety. At this time there is little information to verify dispersal of pathogens by dust locally, or to define the extent to which hedgerows provide their intended services to both wildlife and crops.

Removing wetland or riparian vegetation: Riparian vegetation provides terrestrial habitat, aquatic habitat, stream bank stability, shade, and large woody debris. Vegetative debris in waterways may increase retention of sediment moving in them, thereby improving water quality downstream and contributing to healthy watershed functions. The vegetation provides ecological services that support local wildlife populations dependent upon intact vegetation around water sources for habitat and food (Kocher and Harris 2007).

Long, intact riparian corridors can provide regionally important wildlife movement corridors for both aquatic and terrestrial animals (Penrod *et al.*, 2001). The unique qualities of riparian zones may make them habitat for a particularly diverse population of wildlife (Naiman *et al.* 1993). Local research in a restored riparian zone

[23] It should be noted that reasons other than food safety concerns may discourage growers from using some non-crop vegetation. For example, an economically significant pest that vectors a viral disease in lettuce is associated with the landscaping plant alyssum (often inter-planted with organic lettuce to attract beneficial insects) and ice plant (commonly planted for erosion control) (Bryant, 2008). Koike *et al.* (2009) documented that thrips on alyssum plants were carrying a virus that causes *Impatiens necrotic spot virus* (INVS) in lettuce. Growers interviewed in the course of researching this report also noted concerns about dispersal of weed seeds from unmanaged non-crop vegetation (e.g., vegetation that grows in drainage ditches without intentional planting).

demonstrated that many local species use riparian corridors, and that restoring damaged or cleared riparian vegetation to support wildlife is challenging and expensive, and requires close attention to original features to ensure that appropriate habitat characteristics are restored (Queheillalt and Morrison 2006). Maintenance of wide, well-vegetated riparian zones appears to be very important for large predators, such as the mountain lion. Hilty and Merenlender (2004) found that mountain lions were 11 times more likely to be found in riparian zones than in surrounding vineyards.

Riparian habitat was listed as a key feature in 65% of the wildlife corridors Penrod et al. (2001) identify in the Central Coast region. Local river systems and their riparian boundaries, including the Salinas River, Santa Ynez River, Uvas Creek, Llagas Creek and San Antonio Creek, were all specifically mentioned as linkage features in the corridors (Penrod *et al.*, 2001). The riparian corridors along these rivers and streams provide important habitat connectivity for large and small mammals, southern steelhead and neotropical migratory birds (Penrod *et al.* 2001).

Increased canopy cover in riparian zones may prevent water temperatures from rising during warm seasons, thereby improving survival of some aquatic species (Kocher and Harris, 2007). Many creeks and rivers within the Central Coast region, including the Salinas River, are designated as **Critical Habitat** for the steelhead, which is federally listed as Threatened (NMFS 2005). Adequate water quality, including cool water temperatures, are necessary for steelhead to persist in areas of spawning and rearing habitat. During the summer, the cover and shading provided by riparian vegetation is essential to keeping water temperatures cool enough for the species (David Boughton, Research Ecologist, NOAA, personal communication). High water temperatures and poor water quality adversely affect steelhead both by direct effects and by changing competition factors with more tolerant species (Moyle and Williams 1990). Riparian vegetation is also critical in steelhead management as it provides large debris in the waterways, which creates changes in stream flow that facilitate abundance of food sources upon which steelhead rely (Thompson *et al.* 2006). Also, insects falling off of riparian vegetation into the water are an important source of food for steelhead (Rundio and Lindley 2008). Aquatic macroinvertebrate populations tend to be greater in and near riparian zones with vegetation. The explanation for this finding is not yet clear, but suggests that riparian vegetation may be important to ecological balance of aquatic life in ways that are not yet fully understood (Anderson *et al.* 2003).

The discussion at the end of Part II explains the impact of food safety related changes on the ability to use recently flooded land. Removal of riparian vegetation is practically certain to increase the amount of sediment that enters waterways and moves downstream, potentially carrying pollutants (e.g., pesticides) that adhere to sediment and have adverse impacts on steelhead trout and wildlife near riparian zones.

**Reduced construction and discontinued use or removal of engineered water bodies**: Engineered water bodies specifically mentioned in the survey include ditches and farm ponds, which may include irrigation reservoirs, irrigation runoff recovery ponds, and sediment basins. These are management tools that growers use to receive, capture or store excess water, capture sediment or convey water safely across a property. Their decision to discontinue use of such strategies should be viewed as loss of the erosion control or other resource management benefits they provide, not destruction of natural habitat. Nonetheless, these systems are noted to have critical ecological value for some wildlife. In many regions, financial resources and technical support have been offered to growers as an incentive to manage these water sources to support wildlife (Wolinsky, 2005).

As noted above, the threatened California red-legged frog may be found in Central Coast region irrigation reservoirs (Swaim Biological, Inc., 2007). Information documenting use of these water sources by wildlife is not extensive, but as noted above, the surveys that have been published list several species of snakes, frogs, salamanders and birds that have been observed in farm ponds, particularly where there is suitable terrestrial habitat nearby. The impact of removing these water bodies is dependent upon factors such as their proximity to suitable terrestrial habitat, other water bodies, and how they are managed (e.g., Does water level fluctuate? Are they seasonally drained? Are they treated with copper sulfate? Does the water or sediment contain high levels of contaminants?)

Sediment detention basins (also called sediment ponds or settling ponds) hold storm water and tail water, allowing sedimentation (soil to drop out of water and settle to the bottom) before water is discharged, thus preventing sediment from entering nearby water bodies. They may also reduce flooding risk by managing surges in runoff (NRCS 2008). Sediment basins are well established management practices in many farm environments. Although they do not completely address water quality concerns, they are widely accepted as at least partially effective as a component of a suite of practices to reduce nutrient, sediment and contaminant loads in water. As noted above in Hunt *et al.* (2007, 2008) and Anderson *et al.* (2008), some pesticides are removed with sediments as they settle out. Even if these management practices do not completely address sediment reduction goals, they may provide important improvements in water quality relevant for local wildlife. For example, Wood *et al.* (2009) found that western toad tadpoles could tolerate turbidity at low levels but not higher levels, such as those of untreated agricultural discharge.

Another key function of sediment detention basins is to capture eroded soil from cropland and prevent it from being transported downstream where it will accumulate in lower gradient channels and waterways. Sediment basins, therefore, play a critical role in reducing flooding frequency by detaining runoff and keeping local drainages open during winter storm events. If food safety requirements result in the abandonment of sediment basins, then downstream farm flooding will increase unless channel dredging is increased. This, in turn, would reduce growers' ability to use flood-prone acres, since flooded land is considered a food safety risk.

To the extent that engineered water bodies used to support water quality improvement (e.g., settling ponds, use of VTS to reduce sediment, nutrient, pesticide and pathogen loads prior to discharge) are abandoned, it is practically certain that unless other management practices are substituted to address loss of VTS services, water quality at the farm level will be adversely affected. Volume of sediments and certain pesticides entering waterways are particularly likely to increase. This impact will likely be more pronounced in areas without tiled drainage systems.

**Destruction of natural water body by draining or filling**: Removal of water sources in a region characterized by a long dry season is likely to adversely affect local and migratory wildlife populations. It will certainly adversely affect any animals living in the water source, such as fish or amphibians depending upon it for a stage of the life cycle. If natural water bodies are habitat for endangered or protected species, their destruction may be deemed unlawful (Symonds 2008). Both locally and nationally, many endangered plant and animal species depend on increasingly fragmented wetlands. These areas often support concentrated populations of sensitive species, in part because so much original wetland area has been converted to other land use (Noss *et al.*, 2001).

Wetlands also provide many of the services described above for VTS, as they are essentially natural VTS, though natural wetlands may become less effective over time if channels form that allow water to flow through them more rapidly with less contact with vegetation (Knox *et al.* 2008). Locally, Dayton *et al.* (2006) demonstrated that nitrate concentrations in a natural wetland were greatest where farm runoff entered the wetland, and decreased as the water flowed through the wetland. Knox *et al.* (2008) demonstrated that wetlands may be capable of retaining pathogens, but that these same pathogens may be released later if a scouring flow passes through the wetland.

Wetlands may also mitigate flood effects by temporarily holding water during flood peaks, and subsequently allowing drainage downstream or to groundwater drainage (Potter 1994). Removal of natural water bodies is practically certain to have adverse impacts on wildlife and water quality.

***Summary of Environmental Impacts***: The degree to which on-farm management strategies adopted in response to food safety concerns may have generated adverse impacts on ecological health is not known at this time. The impact of shifting management strategies is not well defined because there is not quantitative data to describe the extent to which grower reported actions occur in the landscape. Acreage affected, number of water bodies filled, type of vegetation removed, and many other details are necessary to determine *actual* impact. The intent of this review is to provide background information to describe the operation and potential impacts of these strategies in Central Coast irrigated row crop systems.

The discontinued use of appropriately placed, and properly designed and maintained vegetated practices may also reduce the potential for other interdependent practices to protect water quality at a particular site. A combination of numerous strategies, including use of materials for treatment of field or tailwater, improved irrigation and nutrient management technologies, and continued adaptation of conservation practices for local conditions, provides innovative ways to address long standing water quality problems. If vegetation is lost from some farms as a component of these strategies, greater reliance on the other components will be required.

Adverse impacts on amphibians from both direct attempts to eliminate them, and indirect impacts of removal of water sources, are also practically certain if extensive removal of water bodies occurs in the farm landscape. Also practically certain is adverse impact on local steelhead and other aquatic species if significant riparian vegetation removal proceeds. Impacts on other wildlife are difficult to assess without more information regarding the extent to which wildlife use existing farm resources (non-crop vegetation and water bodies) as habitat.

***Cumulative and Synergistic Effects***: This report has not thoroughly considered cumulative and synergistic environmental effects related to food safety practices in the Central Coast region, although it is reasonable to expect that they occur. Cumulative impacts result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.[24] Synergistic effects occur when interactions produce more than additive effects, and are well documented throughout the natural world (e.g., Cunningham and Cunningham 2008, Primack 2008, Wright 2007). With synergistic effects, the total impact of two or more threats – such as chemical exposure and habitat removal – can exceed what would be expected from their independent effects (Groom *et al.* 2008).

**Cumulative effects** typically result from multiple stressors. For example, increased hunting of a certain species for food safety concerns may not lead to significant adverse effects on the population. But when combined with other stressors – such as increased chemical ingestion, exposure to sound cannons, the need to navigate around more fences, and reduced habitat in which to find shelter, mates, and food – the combined effect may prove lethal. D'Amore *et al.* (2009) describe an example of this in the Elkhorn Slough area of Monterey County. In this area and across many parts of the region, the cumulative effect of habitat fragmentation and degradation, combined with the well-documented adverse impacts of non-native bullfrogs on the threatened California red-legged frog (D'Amore *et al.*, 2009: Doubledee *et al.* 2003; Lawler *et al.* 1999) has led to declines in red-legged frog populations.

Regarding synergistic impacts, removal of vegetation, application of **copper sulfate**, and other management practices documented to occur in the Central Coast region may mix in particularly lethal combinations that scientists have not begun to analyze. Documenting cumulative and **synergistic effects** in the Central Coast region could require years of intensive research.

[24] See CEQ document referring to National Environmental Policy Act. See http://www.blm.gov/pgdata/etc/medialib/blm/wy/information/NEPA/cfodocs/howell.Par.8634.File.dat/20ch5.pdf

# PART IV Co-Management and Key Issues

## A. What is Co-Management?

As described above, pressures from buyers and auditors have resulted in reduced use of certain in-field conservation management practices, with serious environmental and food safety implications. Understandably, some authors have described this as a "conflict" or "apparent conflict" between food safety and environmental protection (Stuart *et al.* 2006, Bianchi *et al.* 2008, Crohn and Bianchi 2008). The conflict pitches two largely supported societal goals – public health and environmental protection – against one another.

In an attempt to achieve both goals, stakeholders in the Central Coast region are currently working towards "**co-management**" strategies. These stakeholders include growers, environmental non-profits, farm organizations, government agencies, produce companies, and industry trade organizations. The current **co-management** challenge and the key issues stakeholders describe in the Central Coast region are an important case study to evaluate as new food safety standards are applied in other regions or nationally.

While "**co-management**" can be used in different ways, here it is defined as *an approach to minimize microbiological hazards associated with food production while simultaneously conserving soil, water, air, wildlife, and other natural resources.* The term co-management has a long history in fisheries and other natural resources where it implies multiple stakeholders jointly managing the resource base in a way that balances protection with production (e.g., Pomeroy and Rivera-Guieb 2005, Wilson *et al.* 2003). Within food safety, co-management has roots in a 2007 conference organized by University of California in cooperation with agency and industry stakeholders (Bianchi *et al.* 2008). It is based on the premise that food safety and ecological health goals are attainable and compatible.

## B. Towards Co-Management for Food Safety and Ecological Health

**Co-management** for food safety and ecological health has great appeal for growers. The 2009 grower survey noted that eighty percent (80%, n = 123) of growers agreed or strongly agreed that it is their responsibility to protect food safety on their farms. Less than 1% (n = 1) disagreed and the rest either had no opinion or did not answer the question (RCD 2009). Similarly, 80% (n = 123) agreed or strongly agreed with the statement, "I feel it is my responsibility to protect water quality and the environment on my farm." Less than 2% (n = 3) disagreed or strongly disagreed with the statement, and the rest either expressed no opinion or did not answer the question (RCD 2009). Growers clearly value food safety and ecological health and are committed to working towards both goals. **Co-management** allows growers to manage for both goals while also maintaining economic viability.

**Co-management** is science-based, adaptive, collaborative, commodity-specific, and site specific. *Science-based* means building management practices upon a solid scientific foundation. *Adaptive* entails staying current with new scientific findings and incorporating them into management decisions. *Collaborative* encompasses tapping expertise held by resource agency staff, scientists, growers, food safety professionals, and others to manage for both environmental and food safety goals. *Commodity-specific* involves matching management practices to specific crops rather than adopting a "one size fits all" approach. Last, *site specific* implies knowing the conditions under which a given practice does (or does not) accomplish food safety and conservation goals.

With respect to the last principle (*site specific*), **co-management** avoids absolutes. It rejects the notion that a given practice is categorically good or bad. Instead, co-managers apply practices in ways that maximize their contribution to food safety and ecological health. Scientifically grounded "*if...then...*" statements can be helpful in this regard by clarifying the conditions under which a practice is most advisable. For example

- *If* a field sits directly adjacent to a pasture and downslope from it, *then* a vegetated buffer is useful for mechanical filtration of pathogen-containing manure particles before they enter the farm.
- *If* a field sits next to a road traversed by manure-carrying trucks, *then* planting hedgerows or windbreaks may help intercept windblown dust particles that might transport pathogens onto the field.
- *If* a field contains Brussels sprouts, artichokes, or other crops that are cooked before eating (which kills bacteria), *then* a different set of food safety measures than those for produce that is eaten raw may apply.

While specific recommendations lie beyond the scope of this report, these examples show the kind of **co-management** strategies possible. The main point is to provide useful, concrete guidance for accomplishing both food safety and ecological health, rather than make blanket statements about practices being appropriate or inappropriate, or prioritizing one goal to the detriment of the other.

Several challenges to **co-management** exist, and Central Coast stakeholder groups continue to work towards defining specific **co-management** strategies. Efforts to achieve co-management began with numerous industry led meetings, revisions of food safety and conservation guidelines, and a 2007 conference of scientist and stakeholders (Bianchi *et al.* 2008). They have continued with creation of a "Farm Food Safety and Conservation Network" of diverse stakeholders that meets monthly to facilitate **co-management** efforts.[25]

Qualitative interviews revealed several grower attempts to co-manage in their production areas. For example, growers with diverse operations have temporarily shifted where crops are grown in order to reduce proximity of vegetated conservation practices to leafy greens.[26] Other growers who are subject to private standards from produce firms negotiated or altered business arrangements in order to continue the use of conservation practices. While these represent small steps, regional stakeholders continue to refine management guidelines.

### C. Key Issues

Stakeholders face many challenges while working toward **co-management**. This section presents five key issues related to food safety that are critical to ongoing **co-management** efforts as well as the development of future policy. These issues have been identified by multiple sources, including:1) the 2007 co-management conference mentioned above; 2) the Farm Food Safety and Conservation Network; 3) interviews with regional experts; 4) the 2007 and 2009 grower surveys; and 5) authors' extensive interactions over a 6-month period with this project's 36-person Technical Advisory Committee, which served as a *de facto* co-management focus group.

Key food safety issues that impact **co-management** include: the use of private corporate food safety program requirements, liability and litigation risk, concerns about possible effects of national food safety standards, the role of value-added products, and the lack of scientific information. Understanding and addressing these issues could greatly aid co-management efforts and will be critical when considering new food safety policies.

---

[25] The mission of the Network is "to facilitate the coordination of related organizations to support the agricultural industry's efforts to reduce food safety risks through methods which also minimize or avoid impacts to water quality, wildlife and habitat through education, training, research, communication and outreach."
(http://www.awqa.org/networkwiki/index.php?title=NetworkWiki:Community_Portal)

[26] Growers indicate that even if sufficient acreage exists to buffer leafy greens by growing them in the interior of a large field, crop rotation requirements make this a short-term solution.

**Private Corporate Food Safety Program Requirements**

Private corporate food safety programs may be created and managed by processors, shippers, major buying organizations, and/or third-party auditing companies, and often vary significantly from state-sanctioned standards such as the LGMA (Produce Safety Project 2009, RCD 2009). These programs have arisen for multiple purposes, not the least of which is to minimize the legal risk described above. One-third of the 154 participants in the 2009 grower survey reported being held to more than one set of food safety standards (RCD 2009). Based primarily on interview and survey data, this section raises seven issues surrounding private corporate programs' key role in driving on-farm practices that cause environmental and other concerns.

*Lack of transparency*. In many cases, standards used by private food safety programs are considered proprietary information and companies insist that suppliers sign a confidentiality statement precluding them from discussing or otherwise sharing the standards. Standards used by businesses in the food safety inspection industry (e.g., Primus Labs and NSF Davis Fresh) and other third-party certifier companies hired by buyers to inspect operations, are often subject to less stringent confidentiality requirements. Growers face many challenges planning for co-management, and having to adhere to standards they cannot discuss adds to their concerns. The designation of corporate food safety standards as 'proprietary' allows companies to impose requirements that are not subject to environmental review, posing significant challenges to an analysis of the ecological implications of these standards

Some conservation groups (including The Nature Conservancy) are also concerned that the secrecy surrounding private standards allows companies to impose requirements with unknown environmental and fiscal implications.

*Questionable scientific basis for standards*. Growers, farm organizations, and conservation groups have expressed concern about the scientific support for private corporate food safety standards. Private companies and/or groups of companies appear to have specific requirements for buffer widths and other practices that vary widely from company to company and may not be grounded in scientific data. For example, private standards reviewed for this report revealed up to a 10-fold difference in width requirements for **bare ground buffers** around fields. They also showed 6- to 30-fold differences in post-flood waiting periods before crops can be grown there again. Such discrepancies illustrate the variable interpretation of scientific evidence regarding processes of contamination and how best to manage for contamination risk.

Questions regarding scientific support become a serious concern for growers when compliance with the private standards is costly and/or disrupts management of their farms. A survey of leafy greens growers found that growers' costs for modifications made specifically for LGMA compliance averaged $21,490, or $13.60/acre (Hardesty and Kusunose, 2009). Growers who sell their produce to more than one company may be forced to implement the most stringent of each of the various requirements in order to avoid penalties. Growers, farm organizations, and conservation groups have expressed concern that food safety programs requiring specific practices not only lack a scientific basis, but may also undermine both environmental and food safety goals. Examples include removing vegetated buffers, grassed waterways, and constructed wetlands, all of which can help growers maintain water quality and minimize pathogen risk under certain conditions (see Part III).

*Inconsistent interpretation and application of food safety requirements*. According to interviews conducted in 2007, as well as grower interviews conducted in 2009, inconsistent interpretation and application of private corporate standards by auditors and inspectors persist as major concerns. The 2009 grower survey confirmed these findings. It documented that a higher percentage of growers disagree than agree with statements that food safety auditors/inspectors are consistent in their interpretation of either the LGMA standards or other food safety programs (RCD 2009). For example, 52% of growers who adhere to LGMA requirements disagreed or strongly disagreed with the statement *"Other [non-CDFA] food safety auditors/inspectors are consistent in their interpretation of the LGMA Metrics and audit documents."* Only 23% agreed with the statement and none strongly agreed. The remainder did not answer the question or indicated that they had no opinion. The survey report indicates that insufficient technical capacity may contribute to this problem and recommends that auditors/inspectors possess knowledge of microbiology, human health, agriculture, natural resource management, and other relevant topics (RCD 2009).

Growers interviewed in 2007 and in 2009 report that in many cases auditors intentionally vary interpretation and application based on market conditions. Multiple growers described instances where an auditor rejected a field for food safety concerns only to return a few days later to accept the same crop. Conversely, interviews also document situations where excess supply had led auditors to reject a crop on a minor technicality, i.e., for something that had not been a prior concern (see Appendix L for examples).

One of the 36 technical advisors to this project, Devon Zagory, is the past owner of a food safety auditing company. He was able to help interpret the findings and provide additional context, especially regarding the role that market forces play:

> *"In the absence of government regulation of food safety auditing, a market for produce audit companies has developed. Many companies currently offer food safety audit services and, as is the case in markets, great diversity occurs in auditors and their qualifications. Auditors face no formal requirements or qualifications, nor do they have any explicit educational or licensing requirements. Price competition among auditors and audit companies adds another layer of complexity. Such market forces perhaps inevitably lead to a tendency toward less educated and less qualified auditors. There is also variability in oversight of auditors by the audit companies they represent. Nevertheless, auditors can exert a great deal of influence over growers because a satisfactory audit outcome is often required for market access. This can result in uninformed or even incorrect information and requirements articulated by auditors."*
>
> (Personal communication, Devon Zagory)

*Food safety "arms race."* Growers, environmentalists, and other stakeholders are concerned that food safety standards used by private companies escalate because they are used as a marketing advantage. A Canadian consortium of food industry leaders and government agencies recently agreed that "food safety should be a non-competitive matter" (Chambers 2008). Evidence suggests this is not the reality in the U.S. For example, the Food Safety Leadership Council [27] (FSLC) issued what one of its members (Publix) has called "enhanced" On-Farm Produce Standards. The Western Growers Association called the FSLC standards "the beginning of a destructive food safety 'arms race' where different groups of produce buyers, in an effort to claim that they have safer produce than the next, will impose on fresh produce suppliers ever more stringent, expensive, and scientifically indefensible food safety requirements..." [28] Several other industry consortiums maintain their own private food safety standards, such as the Global Food Safety Initiative, the Safe Quality Food Program, and GlobalGAP.

Interviews with growers support the "arms race" phenomenon. As one grower shared: "Everyone is going above the [LCMA] metrics. It's about ego. Trying to out-food-safety the other guy." The food safety manager on another farm noted, "Standards above and beyond are not based on safety, but are a marketing tool." A *USA Today* article quotes a company employee claiming "the most stringent food safety standards in the country" (Schmit 2006). Growers

[27] FSLC is a consortium of large food retailers including McDonalds, Wal-Mart, Walt Disney, Darden Restaurants, and Publix. The Publix cover letter and FSLC standards are available at:
http://www.perishablepundit.com/index.php?date=11/13/07&pundit=1

[28] Letter downloaded from: http://www.perishablepundit.com/PunditImages/WGAIPublixletter-11-06-2007.pdf

indicate that private standards that exceed officially reviewed programs such as the LGMA increase and further contribute to rising costs associated with escalating requirements.

*Private food safety programs can contravene environmental laws.* Growers indicate that they are in some cases pressured by their buyers or auditors to act in ways that violate environmental laws and regulations. For example, removing vegetation can constitute loss of **Critical Habitat** for species protected under the U.S. Endangered Species Act, several of which occur in Arizona, California, and other leafy greens production areas. The documented removal of conservation practices can also place growers in violation of the U.S. Clean Water Act by increasing nutrient, pesticide, and sediment runoff into rivers and streams, unless growers reduce the runoff in other ways. Vegetation removal that includes native trees could violate local regulation such as Monterey County Ordinance 16.60.030, and would not typically fall under approved agricultural exceptions (Monterey County 2009). As noted earlier, the state highway agency has expressed concern that growers' increased vegetation removal on agency-controlled lands that abut farms could be in violation of environmental laws (Monterey County Farm Bureau 2007).

*Certain food safety program measures appear to focus on goals other than food safety.* Animals that have not been shown to pose a significant risk to crop contamination are targeted in private food safety programs, and growers report taking steps to eliminate these animals as a result. The motivation is not clear, but may include other industry goals. For example, larger animals can consume and/or damage crops; small animals, such as rodents and amphibians, can also be captured by machinery during harvest and processed along with produce. While unpleasant and a target of litigation efforts, this "foreign object" contamination is not necessarily a food safety issue. Rodents and amphibians are not identified as **animals of significant risk** as defined by the LGMA. Growers and conservation groups are concerned that corporate food safety programs that discourage these animals may be aimed at improving food quality rather than food safety. Respondents of the 2009 mail survey who are subject to LGMA standards as well as those subject to other food safety programs reported that they have been told by auditors or inspectors that wildlife that are not considered **animals of significant risk** (birds, amphibians, and rodents) may still be a risk to food safety. Neither the LGMA nor the scientific review in Part III of this report support such claims of significant food safety risk.

*Food safety pressures have caused management changes in operations that do not grow leafy greens and/or crops that are consumed raw.* Personal interviews and results from the 2009 grower survey illustrate how food safety pressures have influenced non-leafy greens operations and even crops that are not consumed raw (cooking kills bacteria and dramatically reduces risks of foodborne illness).[29] According to findings from the 2009 survey, 50-75% of artichoke growers and 60-80% of Brussels sprout growers reported being told by auditors or buyers that some combination of wildlife, vegetation, and/or water bodies are a risk to food safety. Interviews also revealed that many growers who grow leafy greens as well as non-leafy greens crops applied the same food safety measures to all fields. Vegetable growers who do not grow leafy greens reported adopting the LGMA standards for competitive advantage or to appease concerns from buyers. Extending requirements intended to reduce risk in 'ready to eat' produce to crops that are virtually assured of being cooked before being consumed unnecessarily increases both the

[29] Rare exceptions could potentially occur. For example, certain consumers may eat Brussels sprouts and artichokes raw. Also, if a contaminant occurs on the external surface of a product then it could transfer to consumers' hands (and further) before cooking occurs. In general, the agricultural industry prefers to mitigate risk as close to the farm as possible rather than rely on consumer behavior. However, the broad application of measures intended to reduce risk in leafy greens to other, less vulnerable crops in an abundance of caution could have serious ramifications for ecological health and financial sustainability in many agricultural regions.

economic and environmental costs of food safety activities. Results from the 2009 survey show that recent food safety concerns have also affected the strawberry sector.[30]

**Liability and Litigation Risk**

Liability and litigation risk can represent a significant challenge to co-management. Data from interviews indicate that growers face increasing pressure from processors and buyers to accept liability for contaminated product. Starting with a landmark 1963 case, the modern notion of "strict liability" arose in California and has spread to all 50 states and much of the industrialized world (California Supreme Court 1963). The concept has persisted as a driving force in food safety litigation (Stearns 2006). Under strict liability, a person who becomes ill after eating produce needs to demonstrate that the produce was contaminated, was used as intended, and caused the sickness. Having demonstrated this, a plaintiff can sue anyone along the chain of production. Actions that growers, shippers, and others take (or do not take) matter relatively little because the plaintiff does not need to prove "negligence" anywhere along the chain.

Until recently, growers who took basic precautionary steps could significantly reduce risk of food safety liability and litigation. Following voluntary FDA recommendations, they usually carried adequate insurance, had their facilities tested by a certifying laboratory, and used contracts that provided extensive indemnification along the entire supply chain (Gilles *et al.* 2004). These measures provided reasonable protection, especially considering that most involvement in litigation and liability for foodborne illness has focused on retailers.

Recent scientific and technological advances have dramatically altered the legal landscape. Improvements in the traceback of produce to growers, and quick appreciation and identification of outbreaks, have shifted legal attention to other parties in the distribution chain all the way back to the growers. Using genetic fingerprinting, bar codes, and other techniques, scientists can now trace a specific pathogen from a sick person to the processing facility, and from there to the farm where the food was grown. As the chain of evidence has extended back to the individual farm or facility, so too has strict liability. Regardless of where along the supply chain the contamination event may have occurred (typically difficult or impossible to determine), the grower will now likely be swept up in the lawsuits that follow. The result is an ongoing spate of large legal settlements, often for millions of dollars. This has serious implications for growers and for agricultural sustainability in general, including greater challenges regarding insurance (see Appendix L).

Growers have expressed strong concern about how the implementation of on-farm food safety practices influences legal risks. On one hand, they face immense pressure to implement food safety practices that run counter to federal and state environmental regulations. This places them at risk of fines and other penalties. On the other hand, growers who do not fully implement environmentally-damaging food safety practices, yet still manage to sell their crops, face increased food safety litigation risk. Growers fear that food safety legal challenges are unlikely to ease without policy reform. They also anticipate legal issues related to new practices and technologies such as irradiation (see Appendix L). Growers are concerned that a practice that FDA considers voluntary could become mandatory as a result of lawsuits. At least one prominent food safety litigator has already said as much, noting that failure to irradiate may lead to punitive damages because it could "constitute a conscious disregard of a known risk" (Marler 2009).

[30] According to the 2009 RCD mail survey, over 43% of strawberry growers had been told that wildlife was a risk to food safety, 8.7% had been told that non-crop vegetation was a risk to food safety, and 26.1% had been told that water bodies were a risk to food safety. Interviews with 23 strawberry growers (2007-2008) found that approximately 39% now use fences to deter wildlife, 43% use poisoned bait, and 35% use traps for wildlife.

**National Food Safety Standards**

Legislation and ensuing national produce standards could either strengthen co-management efforts or undermine them. Concurrent with legislative initiatives on Capitol Hill is an effort to create a National Leafy Greens Marketing Agreement (NLGMA). Proposed by a group of agricultural associations representing the leafy greens industry, the NLGMA would implement best practices and a corresponding verification program for reducing microbial contamination (see www.NLGMA.org). The proposed NLGMA would be modeled after the California LGMA, and would require USDA approval and administration instead of the FDA. This section highlights several stakeholder concerns regarding possible national standards raised in interviews with regional experts through the development of this report.

*Addressing the food safety "arms race".* National standards created by FDA and/or USDA/NLGMA may inadvertently incentivize private corporations to develop requirements that exceed those national standards. As experienced in California, private corporate standards may create an "arms race" phenomenon, and drive increasingly aggressive on-farm management practices despite a more widely accepted set of standards. New national produce safety guidelines could have the unintended consequence of ratcheting these private standards higher, resulting in increased environmental impacts.

Secrecy surrounding private standards makes it difficult to assess both the level of increased environmental or fiscal impacts these corporate requirements may cause, as well as the information and assumptions that drive them. Interview data from growers suggests that a ratcheting above any new federal standards could occur for multiple reasons including marketing advantage (see above). Growers and other stakeholders are concerned that this could: 1) exacerbate environmental, economic, and other concerns featured in this report; 2) create confusion in the market rather than clarity; 3) perpetuate doubt about the role of science in food safety standards; and 4) generate consumer doubt about the adequacy of the national standards due to the presence of private standards that exceed national requirements.

National standards could help resolve these concerns if the standards clearly require corporate programs to be transparent, science based, and otherwise consistent with the principles of "co-management."

*Ensuring a scientific foundation.* Proposed legislation reviewed for this report calls for the use of best available science. However, as this document illustrates, current scientific understanding of processes of crop contamination is quite limited. Stakeholders are concerned that the current lack of scientific understanding could lead to national standards that stretch beyond what existing science can support, and also are subject to a regulatory process that will be unable to keep up with constantly evolving scientific findings. As noted earlier, scientific studies are already underway that, once completed, should shed important light on the process of contamination. Studies such as these can create significant breakthroughs that should be reflected in national food safety standards on an ongoing basis, making them truly science-based.

*Ensuring Flexibility.* Concerns persist that national standards developed in, and administered from, Washington DC could entail a "one size fits all" approach unsuitable to a diverse range of locations, crops, and production methods. As noted earlier, growers report that 'leafy green' food safety pressures have spilled over into non-leafy greens operations including crops such as artichokes and Brussels sprouts that are cooked before consumption (which kills bacteria). Yet they are required to comply with the same strict standards as crops that are eaten raw. The U.S. produces an immense diversity of crops for multiple end uses, under a wide range of growing conditions and farming practices.

Organic production, which continues to expand throughout the region, requires growers to "maintain or improve the natural resources of the operation" in order to keep their organic certification. National and state organic standards define natural resources to include "soil, water, wetlands, woodlands, and wildlife" (U.S. Department of Agriculture 2007,p. 7). Food safety requirements entailing removal of wildlife, non-crop vegetation, and water bodies may run counter to these organic standards.

**Industry Movement into Value Added Products**

Bagged salads, known as "value-added products," have transformed the produce industry, recently becoming the second biggest selling produce item in U.S. grocery stores (Consumer Reports 2006). Numerous foodborne illness outbreaks have been linked to bagged salads, most notably the 2006 spinach *E. coli* outbreak (CDC 2006). Several growers and conservation organizations strongly believe that bagged products are largely responsible for food safety issues relating to leafy green outbreaks. In October 2009, the U.S. Department of Agriculture funded a 3-year, multi-university study to explore growth of *E.coli* and other pathogens in these products (Swedberg 2009).

What exactly is the purported link between bagged salads and on-farm environmental concerns? The theory is that environmentally destructive on-farm management practices are being required in response to food safety risk that is largely driven by this category of product. In other words, the theory is that large-scale industry movement into bagged products has increased foodborne illnesses outbreaks, which in turn has led to a misguided crackdown on wildlife, water bodies, and non-crop vegetation.

The USDA-funded study will shed light on pathogen growth in bagged products during shipping and storage, but that is not the only concern. Another potential connection centers on how processed salads have contributed to an increase in harvesting by machines – an increase noted in LGMA (2008). Unlike human harvesters, machines inadvertently harvest frogs and other small wildlife that are concealed in crops. Machines process these "foreign objects" (or parts of them) into bags which are shipped to buyers. The resulting consumer reaction may lead buyers to discourage wildlife or habitat that supports wildlife near crops.

Evidence indicates that leafy greens tend to create more illnesses per outbreak than other types of produce. In a recent analysis of 10,421 foodborne disease outbreaks dating back to 1973, CDC researchers noted that "the median size of leafy green-associated outbreaks (18 illnesses) was twice the median size of non-leafy green-associated outbreaks" (Herman *et al.* 2008). Centralized processing plants with larger geographic ranges increase risks of dispersed outbreaks (Altekruse *et al.* 1997). Contaminated lettuce mixed and bagged in a centralized plant can impact more consumers than a single head of contaminated lettuce. In some cases, greens from different states (and/or Mexico) are mixed before packaging. Experts from the produce industry report that cross contamination in wash water is a possibility in leafy greens processing plants (see Appendix L). Consumers as well as those in the produce industry have raised concerns that extended shelf lives of processed products and the plastic packaging itself may promote bacterial growth in bagged products.

Stakeholders continue to discuss and debate the existence of a linkage between incidence of foodborne disease outbreaks and the rise of processed leafy greens products. Several non-profit organizations, as well as experts interviewed, suggest a possible connection, however, no known quantitative studies have explored this question. Insufficient data exist at this time to determine whether a correlation (let alone causation) exists between the rise in value added products and incidence of foodborne illness. Any effort to demonstrate a link would need to take into account numerous important considerations. An initial list of important factors appears in Appendix L.

**The Role of Science**

Scientific research focused on food safety and environmental implications of on-farm management practices remains limited, though several new studies are either planned or already in progress, including the wildlife *E. coli* study mentioned in Part III. Appendix K briefly describes several of these projects.

Based on a 2007 conference, Bianchi, Mercer and Crohn (2008) and Crohn and Bianchi (2008) identify areas that both food safety and ecological health professionals agree require further research: 1) persistence and fate of pathogens in the crop and in conservation practices; 2) pathways by which pathogens move through the crop production system; and 3) identification of environmental conditions that promote pathogen survival and proliferation.[31] This report builds on that list, adding new topics and questions that could guide future research to aid co-management (see Part III).

Filling information gaps will allow stakeholders to make more informed decisions regarding important management tradeoffs. Growers are currently asked to make high stakes decisions with low levels of information, the only certainty being that if anything goes wrong they will be held accountable in both legal and public opinion. It is important to acknowledge that even the best scientific efforts will not answer every question or generate 100% certainty. Policy makers and others must make difficult decisions and move forward based on the best available information filtered through societal values. As noted in Bianchi, Mercer, and Cohn (2008), the key is to institute a coordinated process that fills the most critical research gaps on a systematic and continuous basis so that high quality information is regularly available.

[31] The following website provides a complete summary of conference outcomes and results: http://groups.ucanr.org/wqfsconf/

## Conclusion

Pathogenic contamination events in fresh produce are, fortunately, extremely rare relative to the amount of produce consumed. The rarity of these events makes detailed understanding of how and why they occur evasive. Improved scientific methods (e.g., source tracking) are helping researchers follow pathways in the landscape to more precisely identify and define important sources and processes of contamination. However, critical information remains poorly defined, and therein lies the challenge for co-management. How do we navigate risk when the comfort of scientific certainty remains unavailable?

Because the stakes for human health are so high, lack of certainty about the details of how pathogen contamination occurs does not allow growers to delay response. On the contrary, it has led food industry members to identify a broad suite of possible food safety risks, and to devise management protocols that attempt to minimize those risks. This broad focus has generated concerns that efforts to minimize food safety risk may increase impacts on ecological health, in particular water quality and wildlife populations. Acknowledgement of impacts of various management practices to both food safety and ecological health is essential to forge co-management strategies that capture the best available science and ensure a safe and sustainable food supply. Further, decisions made with incomplete risk information ultimately reflect the values of growers, industry leaders and society at large.

Substantial evidence indicates that food safety measures at times run counter to ecological health goals. The extent to which the contradiction has led, or will lead, to measurable impact on ecological health is uncertain, in part because available information fails to quantify and provide detail regarding changes in practices. It is also hard to quantify because the precise ecological value of conservation practices intended to address water quality, in particular, is poorly defined. An analysis of studies in the region found little conclusive evidence of improved water quality despite reports of substantial implementation of conservation practices (Conley *et al.* 2008). On a smaller scale, and in a unique highly erodible setting, the Elkhorn Slough area in Monterey County has recorded impressive gains in soil conservation and resultant decrease in sediment loads in local waterways (NRCS 2006).

Despite media claims of a "scorched earth" policy being carried out (e.g., Lochhead 2009, Lovett 2008, Abraham 2007, and grower interviews) no studies have yet attempted to quantify environmental changes associated with food safety practices on the Central Coast. That said, at least five adverse environmental impacts are likely to occur due to destruction of riparian vegetation, use of **anticoagulants**, and removal of both natural and engineered water bodies. In some cases (e.g., replacement of vegetated buffers with **bare ground buffers** or removal of dust trapping hedgerows) altered management practices can potentially increase both food safety risk and environmental damage.

Limited information regarding contamination processes has created significant challenges for co-management, especially regarding the role of wildlife. Investigations of foodborne illness outbreaks necessarily occur after something bad has already occurred. Since it would be unethical to create a contamination event intentionally (i.e., a robust "controlled" study that makes people sick), scientists face the formidable task of trying to piece things together after a contamination event has already occurred. The results of investigations can provide important information in understanding management practices that might reduce contamination. But because wildlife are considered potential sources of pathogens, risk management strategies have focused on completely excluding wildlife from the farm, including species for which the literature shows low (or no) frequency of pathogens. Growers report changes in practices involving non-crop vegetation and water bodies on farms that reflect uncertainty regarding risks from wildlife and how these features may attract wildlife. These actions widen the scope of influence to include impacts on water quality as well as wildlife and their habitat.

Several studies are currently underway to examine the sources and vectors of pathogens in the Central Coast, as well as how vegetation may reduce the transport of pathogens in agricultural settings. Further evidence may suggest that the exclusion of wildlife and the removal of vegetation, water bodies, and conservation practices are not the best way to manage food safety risk. If standards are to be science based, it is important for food safety programs to adapt promptly in ways that reflect the most recent scientific findings.

**Towards Co-Management**

Co-management has been defined in this report as *an approach to minimize microbiological hazards associated with food production while simultaneously conserving soil, water, air, wildlife, and other natural resources.* It is based on the premise that farmers want to produce safe food, desire to be good land stewards, and can do both while still remaining economically viable. Many Central Coast stakeholders are currently working towards co-management but it is not yet a mainstream approach, and they face many challenges from the various food safety programs they often must accommodate to sell their produce. Success in instituting a co-management approach will require those involved in both food safety and ecological health management to increase awareness of each others' concerns and to adjust standards and guidelines accordingly.

The report notes several food safety issues that may impact the success of co-management. These issues remain the primary areas of concern expressed by stakeholders involved in the co-management process and addressing them may be critical if significant progress is to occur. Focused discussion with a wide range of stakeholders undertaken as part of this case study indicates concern about the role of liability, private corporate food safety standards, potential implications of national food safety standards, value-added processed produce, and insufficient scientific information.

Many of these challenges remain controversial and unresolved, and recommending solutions to them lies beyond the scope or intent of this report. Nevertheless, it is critical to understand stakeholder concerns in order to move forward with co-management efforts. These same issues are also important to consider for development and implementation of food safety programs to be applied in other regions or nationally.

**Moving Forward**

This report provides a snapshot of an evolving issue. Co-management continues to be a challenge, and regional stakeholders will continue to use the best available science to the extent possible to help inform farm-management practices for both food safety and ecological health. As these are both highly valued public goals, it is in the best interest of stakeholders to work towards co-management rather than exclude one goal or the other. Co-management will benefit from additional scientific information and from increased communication between involved parties. A variety of stakeholders participating in the co-management process far beyond the boundaries of California's Central Coast should find use for this report's findings. The report indicates that clear scientific knowledge gaps exist regarding pathogen transport, the role of wildlife, and other key factors. Future studies designed specifically with co-management goals in mind will be of particular use.

Through identifying the range of management changes and the sources of pressure driving these changes, this report also indicates the importance of broad representation in future co-management efforts. The clear commitment to co-management demonstrated by many stakeholders in the region presents an important opportunity for collaborative efforts to ensure that on-farm management practices evolve in ways that reflect the dual goals of food safety and ecological health. Such collaborative, co-management efforts can and should play a critical role in making fresh produce both safe and sustainable for years to come

## Literature Cited

Abraham, K. 2007. Sterile Spinach, Scorched Earth: In the push to eliminate *E. coli* risk, produce handlers are forcing local farmers to unravel conservation practices. *Monterey Herald*, Nov 21, 2007.

Adesiyun, A.A., A. Steward-Johnson, N.N. Thompson. 2009. Isolation of enteric pathogens from bats in Trinidad. *Journal of Wildlife Diseases*, 45:952-961.

Altekruse, S. F., M. L. Cohen.1997. Emerging foodborne diseases. Emerging Infectious Diseases 3(3): 285-293.

Anderson B.S, Phillips BM, Hunt JW, Largay B, Shihadeh, R. 2008. Pesticide and toxicity reduction using vegetated treatment systems and Landguard OP-A. Data Summary and Final Report. Central Coast Regional Water Quality Control Board, San Luis Obispo, CA.

Anderson, B.S., J. W. Hunta, B. M. Phillipsa, P. A. Nicelya, V. de Vlamingb, V. Connorc, N. Richard, B. and R. S. Tjeerdemaa. 2003. Integrated assessment of the impacts of agricultural drainwater in the Salinas River (California, USA). *Environmental Pollution*, 124(3):523-532.

Armstrong, G.L., J. Hollingsworth, and J.G. Morris, Jr. 1996. Emerging Foodborne Pathogens: Escherichia coli O157:H7 as a Model of Entry of A New Pathogen into the Food Supply of the Developed World. *Epidemiology Review* 18(1):29-51.

Atwill, E. R., R. A. Sweitzer, M. D. G. C. Pereira, I. A. Gardner, D. Van Vuren, and W. M. Boyce. 1997. Prevalence of and associated risk factors for shedding Cryptosporidium parvum oocysts and Giardia cysts within feral pig populations in California. Applied and Environmental Microbiology 63:3946-3949.

Atwill, E., Pereira, M., Alonso, L., Elmi, C., Epperson, W., Smith, R., Riggs, W., Carpenter, L., Dargatz, D., and Hoar, B. 2006. Environmental load of Cryptosporidium parvum oocysts from cattle manure in feedlots from the Central and Western United States. *Journal of Environmental Quality*, 35:200-206.

Atwill, E.R. 2008. Implications of Wildlife in *E. coli* Outbreaks Associated with Leafy

AWQA. 2008. AWQA Accomplishments 2007-2008. Salinas, CA: Agriculture Water Quality Alliance (www.awqa.org).

Beier, P. and R.F. Noss. 1998. Do Habitat Corridors Provide Connectivity? *Conservation Biology*, 12(6):1241-1252.

Beretti, M. and D. Stuart. Food Safety and Environmental Quality Impose Conflicting Demands on Central Coast Growers. *California Agriculture* 62(2):68-73.

Beuchat, L. R. 1996. Pathogenic microorganisms associated with fresh produce. Journal of Food Protection. 59(2): 204-216.

Beuchat, L.R. 2002. Ecological factors influencing survival and growth of human pathogens on raw fruits and vegetables." Microbes and Infection 4: 413-423.

Beuchat, L.R. 2006. Vectors and conditions for preharvest contamination of fruits and vegetables with pathogens capable of causing enteric diseases. *Br. Food Journal*, 108:38-53.

Beutin, L., D. Geier, S. Hartmut, S. Zimmerman and F. Scheutz. 1993. Prevalence and some properties of vertoxin (Shiga-like toxin) producing *E. coli* in seven different species of healthy domestic animals. *Journal of Clinical Microbiology*, 31:2483-2488.

Bianchi, M. Mercer, K. and D. Crohn. 2008. Resolving conflicting priorities concerning food safety issues in leafy green vegetatbles. Proceedings of the 23rd Vertebrate Pest Conference, pg. 7-15.

Bianchi, M., Mountjoy, D. and A. Jones. 2008. The Farm Water Quality Plan. San Luis Obispo, CA: University of California, Division of Agriculture and Natural Resources.

Booz, Allen, Hamilton. 2009. Produce Safety Summit: Implications of Mandatory Produce Safety Standards Washington DC: Booz, Allen, Hamilton and the Georgetown University Produce Safety Project.

Boxall, B. 2009. Wildlife found to be unlikely *E. coli* culprit. *Los Angeles Times*, April 11, 2009. Accessed online July 9, 2009. http://articles.latimes.com/2009/apr/11/local/me-ecoli11

Brabben, A. D. D.A. Nelson, E.Kutter, T.S. Edrington, T.R. Callaway. 2004. Approaches to controlling Escherichia coli O157:H7, a foodborne pathogen and an emerging environmental hazard. *Environmental Practice*, 6:208-229.

Brakes, C.R. and R. H. Smith. 2005. Exposure of non-target small mammals to rodenticides:short-term effects, recovery and implications for secondary poisoning. *Journal of Applied Ecology*, 42:118-128.

Brandl, M.T., 2006. Fitness of human enteric pathogens on plants and implications for food safety. *Annual Review of Phytopathology*, 44:367-392.

Branham, L. A., M. A. Carr, C. B. Scott and T. R. Callaway. 2005. *E. coli* O157:H7 and *Salmonella* spp. in white-tailed deer and livestock. *Current Issues in Intestinal Microbiology*, 6:25-29.

Briggs, J.A., T. Whitwell, M.B. Riley. 1999. Remediation of herbicides in runoff water from container plant nurseries utilizing grassed waterways. *Weed Technology*, 13(1):157-164.

Brittingham, M., S. Temple and R. Duncan. 1988. A survey of the prevalence of selected bacteria in wild birds. *Journal of Wildlife Diseases*, 24(2):299-307

Bryant, D. 2008. Mystery persists with INSV coastal lettuce. *Western Farm Press*. Dec. 12, 2008. Accessed online July 7, 2009 http://www.westernfarmpress.com/vegetables/insv-lettuce-1212/index.html.

Bulger, J.B., N.J. Scott, R.B. Seymour. 2003. Terrestrial activity and conservation of adult California red-legged frogs *Rana aurora draytonii* in coastal forests and grasslands. *Biological Conservation* 110:85-95.

Bureau of the Census, U.S. Department of Commerce. 1996. Per capita utilization of selected commercially produced fresh fruits and vegetables: 1970-1994. Statistical Abstract of the Unites States, 116th Edition. Washington DC: US Government Printing Office.

CA Agricultural Resources Directory. 2009. County Statistical Data. Accessed online: www.cdfa.ca.gov/statistics.html

CA EDD 2006. California's Agricultural Employment. California Employment Development Department. Accessed online: http://www.labormarketinfo.edd.ca.gov/?pageid=158

CA Farm Bureau. 2009. Leafy greens safety program serves as national model. News Release. June 3, 2009. Accessed at: http://www.cfbf.com/agalert/AgAlertStory.cfm?ID=1319&ck=1EE3DFCD8A0645A25A35977997223D22

Caceres, Victor M., 1998. A foodborne outbreak of cyclosporiasis caused by imported raspberries. Journal of Family Practice. Accessed 9 Jun, 2009. http://findarticles.com/p/articles/mi_m0689/is_n3_v47/ai_21215651/

Caffrey, J., D. Mountjoy, M. Silberstein, and C. Zabin. 2002 "Management Issues" in Changes in a California Estuary: A Profile of Elkhorn Slough. (Caffrey, J., M. Brown, W.B. Tyler, M. Silberstein Eds). Moss Landing, CA: Elkhorn Slough Foundation.

Caffrey, J., M. Brown, W.B. Tyler, M. Silberstein. 2001. Changes in a California Estuary: A Profile of Elkhorn Slough.Moss Landing, CA: Elkhorn Slough Foundation.

Cahn, M.D., T. Suslow, and A. Sbodio, and S. L. Kamal 2009. Using vegetation and polymers to control sediment, nutrients, and bacteria in irrigation run-off from vegetable fields. Program and Abstracts ASHS Annual Conference, 25-28 July 2009, HortScience 44(4): 1068.

California Food Emergency Response Team. 2007. Investigation of an Escherichia coli O157:H7 Outbreak Associated with Dole Pre-Packaged Spinach (FINAL). San Francisco and Alameda, CA: California Department of Health Services and U.S. Food and Drug Administration.

California Supreme Court. 1963. Greenman v. Yuba Power Products, Inc. 59 C2d57 (Jan.24). Los Angeles, California. [http://online.ceb.com/CalCases/C2/59C2d57.htm] CDC http://www.cdc.gov/crypto/

CDC (Center for Disease Control) 2009. Retrieved from: http://www.cdc.gov/obesity/index.html

CDC (Center for Disease Control). 2006. Multistate outbreak of *E. coli* O157 infections, November-December 2006. Retrieved from: http://www.cdc.gov/ecoli/2006/december/121406.htm

CDPR (California Department of Pesticide Regulation). 2008. Sampling for pesticide residues in California Well Water. 2007 Update of the well inventory database for sampling results reported from July 1, 2006 through June 30, 2007 . Twenty-second Annual Report.

Cizek, A., P. Alexa, I. Literak, J. Hamrik, P. Novak and J. Smola. 1999. Shiga toxin-producing Escherichia coli O157 in feedlot cattle and Norwegian rats from a large-scale farm. *Letters in Applied Microbiology*, 28(6):435-439.

Chambers, A. 2008. Comparing Canada's National Industry-led Food Safety Programs in the Fresh Produce Sector with Food Safety Programs Available in Importing Countries: Abridged Report with Additional Comparisons. Ontario, Canada: Monachus Consulting.

Chambers, A. 2008. Comparing Canada's National Industry-led Food Safety Programs in the Fresh Produce Sector with Food Safety Programs Available in Importing Countries: Abridged Report with Additional Comparisons. Ontario, Canada: Monachus Consulting.

Chang, C.W., H. Chung, *et al.* (2001) "Exposure of workers to airborne microorganisms in open-air swine houses." Applied and Environmental Microbiology 67(1): 155-161.

Chan-McCleod, A.C.A. and A. Moy. 2007. Evaluating Residual Tree Patches as Stepping Stones and Short-Term Refugia for Red-Legged Frogs. *Journal of Wildlife Management*, 71(6):1836-1844.

Chapman, P.A., C.A. Siddons, A.T. Cerdon Malo, M.A. Harkin. 1997. A 1-year study of *Escherichia coli* O157 in cattle, sheep, pigs and poultry. *Epidemiology and Infection*, 119(2):245-250.

Chen, Te-Hao. Gross, Jackson A. Karasov, William. Adverse Affects of Chronic Copper Exposure in Larval Northern Leopard Frogs (*Rana Pipiens*). Environmental Toxicology and Chemistry, 26(7)

CIDRAP (Center for Disease Research and Policy. 2007. "California Debates Produce Safety Measures" news release January 26, 2007. http://cidrap.umn.edu/cidrap/content/fs/food-disease/news/jan26growers.htm

Clark, J. P. 1994. Wildlife diseases and man. Vertebrate Pest Control Handbook, 4th Edition. Calif. Dept.of Food and Agriculture, Sacramento, CA, 500-504.

Cobbold, R. and P. Desmarcheller. 2000. A longitudinal study of Shiga-toxigenic *Escherichia coli* (STEC) prevalence in three Australian dairy herds. *Veterinary Microbiology*, 71:125-137.

Cody, S.H., M.K. Glynn, J.A. Farrar, K.L. Cairns, P.M. Griffin, J. Kobayashi, M. Fyfe, R. Hoffman, A.S. King, J.H. Lewis, B. Swaminathan, R. G. Bryant, D.J. Vugia. 1999. An outbreak of *Escherichia coli* O157:H7 infection from unpasteurized commercial apple juice. *Annuals of Internal Medicine*, 130(3):202-209.

Compton, J., Baney, J., Donaldson, S., Houser, B., San Julian, G., Yahner, R., Chmielecki, W., Reynolds, S., and B. Jayarao. 2008. *Salmonella* infections in the common raccoon (Procyon lotor) in western Pennsylvania. *Journal of Clinical Microbiology* 46:3084-3086.

Conley, G., Hoover, B., and S. DeBeukelaer. 2008. Central Coast Water Quality Data Assessment: Final Report on Central Coast Water Quality Data. Monterey, CA: National Oceanic and Atmospheric Administration, Synthesis, Assessment, and Management (SAM) Project.

Consumer Reports. 2006. Bagged salads: the yuck factor. Consumer Reports. November 2006. Online: http://www.consumerreports.org/cro/food/food-shopping/fruits-vegetables/bagged-salads/bagged-salads-11-06/overview/1106_salad_ov_1.htm

Converse, K., M. Wolcott, D. Docherty, R. Cole. 1999. Screening for potential human pathogens in fecal material deposited by resident Canada geese on areas of public utility. USGS National Wildlife Health Center. FWS ALC 14-16-0006. http://www.nwhc.usgs.gov/publications/other/screening_canadian_geese.pdf

Cooley, M., Carychao, D., Crawford-Miksza, L., Jay, M.T., Myers, C., Rose, C., Keys, C., Farrar, J., Mandrell, R. 2007. Incidence and tracking for Escherichia coli O157:H7 in a major produce production region in California. PLoS ONE 2(11): e1159.doi:10:1371/journal.pone.0001159. Online: http://www.plosone.org/article/info:doi/10.1371/journal.pone.0001159

Cooley, M.B., D. Chao and R.E. Mandrell. 2006. *Escherichia coli* O157:H7 Survival and Growth on Lettuce Is Altered by the Presence of Epiphytic Bacteria. *Journal of Food Protection*, 69(10):2329-2335.

Covello, V. and P. Sandman. 2001. Risk communication: Evolution and Revolution. Pages 164-178, In: Wolbarst A. (ed.) Solutions to an Environment in Peril. Baltimore, MD: John Hopkins University Press.

Craven, S. E., N. J Stern, E. Line, J.S. Bailey, N.A. Cox and P . Fedorka-Cray. 2000. Determination of the incidence of *Salmonella* spp., *Campylobacter jejuni*, and *Clostridium perfringens* in free-ranging birds near broiler chicken houses by sample intestinal droppings. *Avian Diseases*, 44:715-720.

Crohn, D. and M.Bianchi. 2008. Research Priorities for Coordinating Management of Food Safety and Water Quality. *Journal of Environmental Quality* 37(4):1411-18.

Cunningham, W., and M.A. Cunningham. 2007. *Environmental Science: A Global Concern (10th edition)*. McGraw-Hill.

CSPI 2009. Cite CSPI testimony from June 2009 testimony. Organics?

CWC. California Wilderness Coalition. 2002. Wildlands Conservation in the Central Coast Region of California. July 2002.

D'Amore, A., V. Hemmingway and K. Wasson. 2009. Do a threatened native amphibian and its invasive congener differ in response to human alteration of the landscape? *Biological Invasions*, Published online February 6, 2009. http://www.springerlink.com/content/943k084q8265210q/

Dabney, S. M., M. T. Moore and M. A. Locke. 2006. Integrated management of in-field, edge-of-field, and after-field buffers. *Journal of the American Water Resources Association* 42(1): 15-24.

D'Amore, A., E. Kirby, M. McNicholas. 2009. Invasive species shifts in ontogenetic resource partitioning and microhabitat use of a threatened native amphibian. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 19:534-541.

Daniels, M.J., M.R. Hutchings, and A. Greig. 2003. The risk of disease to livestock posed by contamination of farm stored feed by wildlife excreta. *Epidemiology and Infection*, 130:561-568.

Davis, F. W., D. M. Stoms, A.D. Hollander, K. A. Thomas, P.A. Stine, D. Odion, M. I. Borchert, J.H. Thorne, M.V. Gray, R.E. Walker, K. Warner, and J. Graae. 1998. The California Gap Analysis Project--Final Report. University of California, Santa Barbara, CA. http://www.biogeog.ucsb.edu/projects/gap/gap_rep.html

Dayton, G.,M. Apodaca, R. Clark, A. Wiskind,J. Oliver and S. Tanner. 2006. Cleaning water by restoring wetlands:Water quality in the Moro Cojo watershed. Presentation at Elkhorn Slough Symposium. http://www.elkhornslough.org/research/symposium/Dayton_WaterQuality_poster.pdf

Dell'Orno, G., S. Morabito, R. Auondam U. Agrimi, F. Ciuchini, A. Macri and A. Caprioli. 1998. Feral pigeons as a source of verocyotoxin-producing *Escherichia coli*, *Veterinary Record*, 142:309-310.

Denys, C. and T. Tscharntke. 2001. Plant-insect communities and predator-prey ratios in field margin strips, adjacent crop fields, and fallows. *Oecologia*, 130(2):315-324.

DFG, 2009. California Department of Fish and Game. Accessed online July 2009, http://www.dfg.ca.gov/wildlife/hunting/deer/

Doubledee, R.A., E.B. Muller, R.M. Nisbet. 2003. Bullfrogs, disturbance regimes, and the persistence of California red-legged frogs. *Journal of Wildlife Management*, 67(2):424-438.

Dowd, B., D. Press, and M. Los Huertos. 2008. Agricultural nonpoint source water pollution policy: the case of California's Central Coast. Agriculture, Ecosystems and Environment 128: 151: 161.

Doyle, M.P. and M.C. Erickson. 2008. Summer meeting 2007 – the problems with fresh produce: an overview. *Journal of Applied Microbiology*, 105:317-330.

Dunn, J. R., J. E. Keen, D. Moreland, R. A. Thompson. 2004. Prevalence of *Escherichia coli* O157:H7 in white-tailed deer from Louisiana. *Journal of Wildlife Diseases*, 40(2):361-365.

Earnshaw, S. 2003. Hedgerows for California Agriculture: A Resource Guide. Community Alliance with Family Farmers. Western Region Sustainable Agriculture Research and Education.

Ehler, L.E., C.G. Pease, R. F. Long. 2002. Farmscape ecology of a native stink bug in the Sacramento Valley. *Fremontia*, 30(3-4);59-61.

Elder, R.O., J.E. Keen, G.R. Siragusa, G.A. Barkocy-Gallagher, M. Koohmaraie, and W.W. Lageid. 2000. Correlation of enterohemorhagic *Escherichia coli* prevalence in feces, hides and carcasses of beef cattle during processing. *Proceedings of the National Academy of Sciences*, U.S.A, 97:2999-3003.

Entrix, Inc. 2009. Salinas River Channel Maintenance Program Biological Assessment. Monterey County Water Resources Agency, Salinas, CA.

Epstein, L.H., C.C. Gordy, H. A. Raynor, M. Beddome, C.K. Kilanowski, and R. Paluch. 2001. Increasing fruit and vegetable intake and decreasing fat and sugar intake in families at risk for childhood obesity. 9: 171- 178.

ERS. Economic Research Service. 2001. Commodity spotlight: lettuce in and out of the bag. Agricultural Outlook. April 2001: 10-13.

Faddoul, G.P. and G. W. Fellows. 1966. A five-year survey of the incidence of *Salmonella* in avian species. *Avian Diseases*, 10:296-304.

Faith, N., Shere, J., Brosch, R., Arnold, K., Ansay, S., Lee, M., Luchansky, J., and C. Kaspar. 1996. Prevalence and clonal nature of *Escherichia coli* O157:H7 on dairy farms in Wisconsin. *Applied and Environmental Microbiology*, 62(5):1519-1525.

FDA, 2001 http://www.foodsafety.gov/~dms/fsefborn.html

FDA, 2005. Letter to California Firms that Grow, Pack, Process, or Ship Fresh and Fresh-cut Lettuce. http://archives.energycommerce.house.gov/Investigations/FoodSafety.110405.FDA.CaliforniaFirms.ltr.pdf

Feare, C.J., M. F. Sanders, R. Blasco and J.D. Bishop. 1999. Canada goose (*Branta canadensis*) droppings as a potential source of pathogenic bacteria. *Journal of the Royal Society of Health*, 119:525-530.

Fenlon, D.R. 1981. Seagulls (*Larus* spp.) as vectors of Salmonellae --- an investigation into the range of serotypes and numbers of Salmonellae in gull feces. *Journal of Hygiene*, 86(2):195-202.

Fiener, P. and K. Auerswald. 2003a. Effectiveness of grassed waterways in reducing runoff and sediment delivery from agricultural watersheds. *Journal of Environmental Quality*, 32(3):927-936.

Fiener, P. and K. Auerswald. 2003b. Concept and effects of a multi-purpose grossed waterway. *Soil Use and Management*.19(1):65-72.

Finz, S. 2009. New vaccine keeps *E. coli* inside cows. *San Francisco Chronicle*, July 2, 2009.

Fischer, J.R., T. Zhao, M.P. Doyle, M.R. Goldberg, C.A. Brown, C.T. Sewell, D. M. Kavenough, C.D. Bauman. 2001. Experimental and field studies of *Escherichia coli* O157:H7 in white-tailed deer. *Applied and Environmental Microbiology*, 67(3):1218-1224.

Fonseca, J.M. and S. Ravishankar. 2007. Contaminated fruits and vegetables are more common than ever. Why? And what can consumers do to protect themselves? *My American Scientist*, 95(6):494.

Foster, G., H.M. Ross, T.W. Pennycott, G. F. Hopkins, I.M. McLaren. 1998. Isolation of *Escherichia coli* O86:K61 producing cyto-lethal distending toxin from free-ranging birds of the finch family. *Letters in Applied Microbiology*, 26:395-398.

Garcia-Munoz, E., F. Guerrero, G. Parra. 2009. Effects of copper sulfate on growth, development and escape behavior in *Epidalia calamita* embryos and larva. *Archives in Environmental Contamination and Toxicology*, 56:557-565.

Garcia-Sanchez, A., S. Sanchez, R. Rubio, J.M. Alonso, J. Hermoso De Mendoza, J. Rey. 2007. Presence of Shiga toxin-producing *E. coli* O157:H7 in a survey of wild artiodactyls. *Veterinary Microbiology*, 121(3-4):373-377.

Gardner, T. and J. McLaughlin. 2008. *Campylobacteriosis outbreak due to consumption of raw peas – Alaska, 2008. State of Alaska Epidemiology Bulletin, October 8, 2008. http://www.epi.hss.state.ak.us/bulletins/docs/b2008_20.pdf*

Gaukler S.M., G. Linz, J. Sherwood, N.W. Dyer, W.B. Bleier, Y. M. Wannemuehler, L. K. Nolan, C. M. Logue. 2009. *Escherichia coli*,*Salmonella*, and *Mycobacterium avium* subsp. *Paratuberculosis* in wild European starlings at a Kansas cattle feedlot. *Avian Diseases*, 53:544-551.

Gaukler, S. M, H. J. Homan, N. W. Dyer, G. M. Linz, W. J. Beier. 2008. Pathogenic diseases and movements of wintering European starlings using feedlots in central Kansas. *Proceedings of Vertebrate Pest Conference*, 23:280-282.

Gentry, R.W., J. McCarthy, A. Layton, L.D. McKay, D. Williams, S. R. Koirala, G.S. Sayler. 2006. Escherichia coli Loading at or Near Base Flow in a Mixed-Use Watershed. Journal of environmental quality. 35(6): 2244-2249.

Gilles, J., Moncreif, P. and B. Sullivan. 2004. Preventative Measures to Protected Against Liability Relating to Foodborne Illness. *Coastal Grower Magazine*. [Salinas?]

Glaser, L. Lucier, G., and G. Thompson. 2001. Lettuce: In & Out of the Bag. Agricultural Outlook (April). Washington, D.C.: United States Department of Agriculture, Economic Research Service.

Goldman, I.L. 2003. Recognition of fruit and vegetables as healthful: vitamins and phytonutrients. Horttechnology. 13: 252-258.

Goodchild, W.M. and J.F. Tucker. 1968. *Salmonellae* in British free-ranging birds and their transfer to domestic fowl. *British Veterinary Journal*, 124:95-101.

Gorny, J.R., H. Giclas, D. Gombas, and K. Means. 2006. "Commodity Specific Food Safety Guidelines for the Lettuce and Leafy Greens Supply Chain." April 25, 2006. http://www.cfsan.fda.gov/~acrobat/lettsup.pdf

Gray, M.J., S. Rajeev, D.L. Miller, A. C. Schmutzer, E.C. Burton, E.D. Rogers, G.J. Hickling. 2007. Preliminary evidence that American bullfrog (*Rana catesbeiana*) are suitable hosts for *Escherichia coli* O157:H7. *Applied and Environmental Microbiology*, 73(12):4066-4068.

Green Produce. Proceedings of 23rd Vertebrate Pest Conference, University of California, Davis, 5-6.

Greenway, M. 2005. The role of constructed wetlands in secondary effluent treatment and water reuse in subtropical Australia. *Ecological Engineering*, 25(1):501-509.

Grimes, T.M. 1979. Observations on *Salmonella* infections of birds. *Australian Veterinary Journal*, 55:16-18.

Groom, M., Meffe, G., and R. Carroll. 2006. *Principles of Conservation Biology* (3rd edition). Sinaur Associates, Sunderland, MA. ISBN 0-87893-518-5.

Guan, S., R. Xu, S. Chen, J. Odumeru, C. Gyles 2002. Development of a procedure for discriminating among Escherichia coli isolates from animal and human sources.

Gupta, S.K., R. C. Gupta, S.K. Chhabra, S. Eskiocak, A. B. Gupta and R. Gupta. 2008. Health issues related to N pollution in water and air. Current Science 94: 1469 – 1477.

Habteselassie, M., Bischoff, M.,Blume, E.,Applegate, B.Reuhs, B., Brouder, S., Turco, R. F. 2008. Environmental Controls on the Fate of Escherichia coli in Soil. Water, air, and soil pollution. 190(1-4): 143-155.

Hancock, D.D. T. E. Besser, D.H. Rice, E.D. Ebel, D.E. Herriott, L.V. Carpenter. 1998. Multiple sources of *Escherichia coli* O157:H7 in feedlots and dairy farms in the Northwestern USA. *Preventative Veterinary Medicine*, 35:11-19.

Handler, N.B., A. Paytan, C. P. Higgins, R. G. Luthy, and A. B. Boehm. 2006. Human development is linked to multiple water body impairments along the California Coast. Estuaries and Coasts 29: 860-870.

Hardesty, S. D. and Y. Kusunose. 2009. Growers' compliance costs for the leafy green marketing agreement and other food safety programs. UC Small Farm Program Research Brief, ANR University of California. http://www.sfc.ucdavis.edu/docs/leafygreens.pdf

Harris, L., Farber, J., Beuchat, L., Parish, M., Suslow, T., Garrett, E., and Busta, F., 2006. Outbreaks associated with fresh produce: incidence, growth, and survival of pathogens in fresh and fresh-cut produce. Comprehensive *Reviews in Food Science and Food Safety*, v.2. Issue s1. p. 78-141.

Haycock, N.E. and G. Pinay. 1993. Groundwater nitrate dynamics in grass and poplar vegetated riparian buffer strips during the winter. *Journal of Environmental Quality*,22(2):273-278.

Hench, K.R., G.K. Bissonnette, A.J. Sexstone, J.G. Coleman, K. Garbutt, J.G. Skousen. 2003. Fate of physical, chemical, and microbial contaminants in domestic wastewater following treatment by small constructed wetlands. *Water Research*, 37(4):921-927.

Henzler, D. J. and H.M. Opitz, 1992. The role of Mice in the epizootiology of *Salmonella enteritidis* infection on chicken layer farms. *Avian Diseases* 36:625-631

Herman, K., T.Ayers, and M. Lynch. 2008. Foodborne disease outbreaks associated with leafy greens, 1973-2006. International Conference on Emerging Infectious Diseases 2008 Program and Abstracts Book. Centers for Diseases Control. [available at: http://www.cdc.gov/eid/content/14/3/ICEID2008.pdf ]

Heron, M., Hoyert, D., Murphy, S, Xu, J., Kochanek, K., and B. Tejada-Vera. 2009. Deaths: Final Data for 2006. National Vital Statistics Reports 57(14). Hyattsville, MD: National Center for Health Statistics, Centers for Disease Control and Prevention. http://www.cdc.gov/nchs/data/nvsr/nvsr57/nvsr57_14.pdf

Heuvelink, A.E., J.T.M. Zwartkruis, C. Van Heerwaarden, B. Arends, V. Stortelder, and E. de Boer. 2008. Pathogenic bacteria and parasites in wildlife and surface water. *Tijdschrift Voor Diergeneeskunde*, 133(8):330-335.

Hill, C. and J. MacDonald. 2008. Medical Entemology Glossary. Purdue University Extension Service. Accessed June 10, 2009 at http://www.entm.purdue.edu/publichealth/glossary.html#v,

Hill, V.R. and M.D. Sobsey. 2001. Removal of *Salmonella* and microbial indicators in constructed wetlands treating swine wastewater. *Water Science and Technology*, 44(11-12):215-222.

Hilty, J.A. and A.M. Merenlender. 2004. Use of Riparian Corridors and Vineyards by Mammalian Predators in Northern California. *Conservation Biology*, 18(1):126–135

Howarth, R.W., A. Sharpley, and D. Walker. 2002. Sources of nutrient pollution to coastal waters in the United States: Implications for achieving coastal water quality goals. Estuaries 25: 656-676.

Hudson, C. R.,C. Quist, M.D. Lee, K. Keyes, S.V. Dodson, C. Morales, S. Sanchez, D. G. White and J. J. Maurer. 2000. Genetic relatedness of *Salmonella* isolates from nondomestic birds in southeastern United States. *Journal of Clinical Microbiology*, 38:1860-1865.

Hughes, L.A., M. Bennett, P. Coffey, J. Elliott, T.R. Jones, R.C. Jones, A. Lahuerta-Marin, K. McNiffe, D. Norman, N.J. Williams, and J. Chantrey. 2009. Risk factors for the occurrence of *Escherichia coli* virulence genes eae, stx1 and stx2 in wild bird populations. *Epidemiology and Infection*, 137:1574-1582.

Hunt JW, Anderson BS, Phillips BM, Largay B, Watson F, Harris K, Hanson E, Beretti M, Schafer R, Brown K, Bern AL. 2007. Effectiveness of agricultural management practices in reducing concentrations of pesticides associated with toxicity to aquatic organisms. Data Summary and Final Report. Central Coast Regional Water Quality Control Board, San Luis Obispo, CA.

Hunt, J. W., B. S. Anderson, B. M. Phillips, R. S. Tjeerdema, H. M. Puckett and V. deVlaming. 1999. Patterns of aquatic toxicity in an agriculturally dominated coastal watershed in California. *Agriculture Ecosystems & Environment* 75(1-2): 75-91.

Hunt, J., B. Anderson, B. Phillips, R. Tjeerdema, B. Largay, M. Beretti, A. Bern. 2008. Use of toxicity identification evaluations to determine the pesticide mitigation effectiveness of on-farm vegetated treatment systems. *Environmental Pollution*, 156:348-358.

Hussein, H.S. 2007. Prevalence and pathogenicity of Shiga toxin-producing Escherichia coli in beef cattle and their products. *Journal of Animal Science*, 85(13 Suppl):E63-72

IPCC. 2004. Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties. Paris, France: World Meteorological Organization, United Nations Environment Program, and the Intergovernmental Panel on Climate Change. [Available at: http://ipcc-wg1.ucar.edu/wg1/Report/AR4_UncertaintyGuidanceNote.pdf]

Iwasa, M, S. Makino, H. Asakura, H. Kobori, Y. Morimoto. 1999. Detection of *Escherichia coli* O157 : H7 from *Musca domestica* (Diptera : Muscidae) at a cattle farm in Japan. *Journal of Medical Entomology*, 36(1):108-112.

Janisiewicz, W.J., W.S. Conway, M.W. Brown, G.M. Sapers, P. Fratamico, R.L. Buchanan. 1999. Fate of *Escherichia coli* O157:H7 on fresh-cut apple tissue and its potential for transmission by fruit flies. *Applied and Environmental Microbiology*, 65:2605-2609.

Jay, M.T. and G. W. Wiscomb. 2008. Food safety risks and mitigation strategies for feral swine (Sus scrofa) near agricultural fields. *Proceedings of 23rd Vertebrate Pest Conference*, University of California, Davis. 21-25.

Jay, MT., M. Cooley, D. Carychao, G.W. Wiscomb, R. A. Sweitzer, L. Crawford-Miksza, J.A. Farrar, D. K. Lau, J.O'Connell, A. Millington, R. V. Asmundson, E. R. Atwill, R.E. Mandrell. 2007. *Escherichia coli* O157:H7 in feral swine near spinach fields and cattle, central California coast. *Emerging Infectious Diseases*, 13(12):1908-1911.

Jijon, S., A. Wetzel, and J. LeJeune. 2007. *Salmonella enterica* isolated from wildlife at two Ohio rehabilitation centers. *Journal of Zoo and Wildlife Medicine*, 38(3):409-413.

Johnsen, G., Y. Wasteson, F. Heir, O.I. Berget, H. Herikstad. 2001. *Escherichia coli* O157:H7 in faeces of cattle, sheep and pigs in the southwest part of Norway during 1998 and 1999. *International Journal of Food Microbiology*, 65:193-200.

Johnston, C.S., C.A. Taylor and J. S. Hampl. 2000. More Americans are eating "5 a day" but intakes of dark green and cruciferous vegetables remain low. *Nutritional Epidemiology* 130: 3063 – 3067.

Jones, A. 2008. Personal Communication from key informant at the Central Coast Regional Water Quality Control Board. San Luis Obispo, CA.

Kadlec, R.H. and R.L. Knight. 1996. Treatment wetlands. Lewis Publishers, Boston.

Kangas, S., J. Takkinen, M. Hakkinen, U-M. Nakari, T. Johansson, H. Henttonen, L. Virtaluoto, A. Siitonen, J. Ollgren, and M. Kuusi. 2008. *Yersinia pseudotuberculosis* O:1 Traced to Raw Carrots, Finland. Emerging Infectious Diseases, 14(12):1959-1961.

Karthikeyan, R., L.C. Davis, L.E. Erickson, K. Al-Khatib, P.A. Kulakow, P.L. Barnes, S.L. Hutchinson, A.A. Nurzhanova. 2004. Potential for plant-based remediation of pesticide contaminated soil and water using nontarget plants such as trees, shrubs, and grasses. *Critical Reviews in Plant Sciences*, 23(1):91-101.

Keene, W.E., E. Sazie, J. Kok, D.H. Rice, D.D. Hancock, V.K. Balan, T. Zhao, M.P. Doyle. 1997. An outbreak of *Escherichia coli* O157:H7 infections traced to jerky made from deer meat. *Journal of American Medical Association*, 277(15):1229-1231

Khaitsa, M.L., D.R. Smith, J.A. Stoner, A.M. Parkhurst, S. Hinkley, T.J. Klopfenstein and R.A. Moxley. 2003. Incidence, duration, and prevalence of *Escherichia coli* O157:H7 fecal shedding by feedlot cattle during the finishing period. *Journal of Food Protection*, 66:1972-1977.

Kirk, J.H., C.A. Holmberg, J.S. Jeffrey. 2002. Prevalence of Salmonella spp. in selected birds captured on California dairies. *Journal of the American Veterinary Medical Association*, 220:359-362.

Knox, A.K. R.A. Dahlgren, K.W. Tate and E.R. Atwill. 2008. Efficacy of Natural Wetlands to Retain Nutrient, Sediment and Microbial Pollutants, *Journal of Environmental Quality*, 37:1837-1846.

Kobayashi, H., J. Shimada, M. Nakazawa, T. Morozumi, T. Pohjanvirta, S. Pelkonen, and K. Yamamoto. 2001. Prevalence and characteristics of shiga-toxin-producing *Escherichia coli* from healthy cattle in Japan. *Applied and Environmental Microbiology*, 67:484-489.

Kocher, S.D. and R. Harris. 2007. Riparian Vegetation, Forest Stewardship Series, University of California, Department of Agriculture and Natural Resources, Publication No. 8240.

Koelsch, R.K.,J.C. Lorimor, and K.R. Mankin. 2006. Vegetative treatment systems for management of open lot runoff: review of literature. *Applied Engineering in Agriculture* 22(1):141-153.

Koike, S., B. Gilbertson, Y-W. Kuo, T. Turini and R. Smith. 2009. Investigation of Tospovirus outbreaks in California lettuce. Project Report for the California Leafy Greens Research Board, April 2008-March 2009. Leafy Greens Research Program. http://calgreens.org/control/uploads/Tospovirus_Outbreaks_in_Lettuce_-_Koike.pdf

Kreith, M. 2007. Wild Pigs in California: The Issues. *AIC Research Brief.* 33, 6 pgs. Accessed online July 9, 2009 http://www.agmrc.org/media/cms/AgMRC_IB33v3_13C1D662ADDAE.pdf.

Kremen, C., R.L. Bugg, N. Nicola, S.A. Smith, R.W. Thorp, N.M. Williams. 2002. Native bees, native plants, and crop pollination in California. *Fremontia*, 30(3-4):41-49.

Kudva, I.T., K. Blanch, C.J. Hovde. 1998. Analysis of *Escherichia coli* O157:H7 survival in ovine or bovine manure slurry. *Applied and Environmental Microbiology*, 64:3166-3174.

Kullas, H. M. Coles, J. Rhyan, L. Clark. 2002. Prevalence of *Escherichia coli* serogroups and human virulence factors in faeces of urban Canada geese (*Branta canadensis*). *International Journal of Environmental Health Research*, 12(2):153-162.

Lawler, S.P., D. Dritz, T. Strange, M. Holyoak. 1999. Effects of introduced mosquitofish and bullfrogs on the threatened California red-legged frog. *Conservation Biology*, 13(3):613-622.

Leafy Greens Handler Marketing Board. 2008. Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens. Sacramento, CA: California Leafy Greens Handler Marketing Board.

Lee & Pierce, Inc. 2008. Draft 2007-2008 Salinas and Arroyo Seco Rivers Emergency Channel Maintenance Application. Salinas, CA: Monterey County Water Resources Agency.

Lee, S.A., A. Adhikari, *et al.* (2006). Personal exposure to airborne dust and microorganisms in agricultural environments. Journal of Occupational and Environmental Hygiene 3(3): 118-130.

LeJeune, J., J. Homan, G. Linz and D. L. Pearl 2008. Role of the European Starling in the Transmission of *E. coli* O157:H7 on Dairy Farms. Proceedings of the 23rd Vertebrate Pest Conference, 31-34.

LeJeune, J.T. and A.N. Wetzel. 2007. Preharvest control of *Escherichia coli* O157 in cattle. *Journal of Animal Science*, 85:E73-E80.

LGMA. Leafy Greens Marketing Agreement. 2009. http://www.caleafygreens.ca.gov/members/resources.asp

Li-Cohen, A. and C. Bruhn. 2002. Safety of consumer handling of fresh produce from the time of purchase to the plate: A comprehensive consumer survey. *Journal of Food Protection* (8):1287-1296.

Lillehaug, A., B. Bergsjø, J. Schau, T. Bruheim, T. Vikøren and K. Handeland. 2005. *Campylobacter* spp., *Salmonella* spp., Verocytotoxic *Escherichia coli*, and Antibiotic Resistance in Indicator Organisms in Wild Cervids. *Acta Veterinaria Scandinavica*, 46(1-2):23-32.

Lochhead, C. 2009. Crops, ponds destroyed in quest for food safety. *San Francisco Chronicle* (July 13).

Locke, M.A., R.M. Zablotowica, and M.A. Weaver. 2006. Herbicide fate under conservation tillage, cover crop, and edge-of-field management practices. In Handbook of sustainable weed management. H.R. Singh, D.R. Batish, and R.K. Kohli (Eds). Haworth Press, New York.

Long, R. and C. Pease. 2005. Farmscaping with native perennial grasses. Grassl Spring, 15:6-7.

Los Huertos, M., L. E. Gentry and C. Shennan 2001. "Land use and stream nitrogen concentrations in agricultural watersheds along the Central Coast of California." Proceedings of the 2nd International Nitrogen Conference on Science and Policy, The Scientific World 2: 615-622.

Lovett, L.M. 2008. Fields of Overkill. *High Country News*, May 26. Accessed July 2, 2008 from: http://www.hcn.org/search?SearchableText=fields+of+overkill

Makino, S., H. Kobori, H. Asakura, M. Watarai, T. Shirahata, T. Ikeda, T. Takeshi, T. Tsukamoto. 2000. Detection and characterization of shiga toxin-producing *Exherichia coli* from seagulls. *Epidemiology and Infection*, 125:55-61.

Marler, B. 2009. Pros and Cons of Irradiation for Fresh Produce Industry: A Legal Perspective. Presentation at the International Food Technologist Annual Meeting, June 6-9, 2009. Anaheim, CA. [LINK: http://www.marlerblog.com/uploads/file/DOC065(1).pdf

Mead, P. S., L. Slutsker *et al.* 1999. Food-related illness and death in the United States. Emerging Infectious Diseases 5(5): 607-625.

Meerburg, B.G., M. Bonde. 2004. Towards sustainable management of rodents in organic animal husbandry. *Njas-Wageningen Journal of Life Sciences*, 52(2):195-205.

Milam, C.D., J.L. Bouldin, J.L. Farris, R. Schulz, M.T. Moore, E.R. Bennett, C.M. Cooper, S. Smith. 2004. Evaluating acute toxic methyl parathion application in constructed wetland microcosms. *Environmental Toxicology*, 19(5):471-479.

Millennium Ecosystem Assessment, 2005. *Current State & Trends Assessment*. Island Press, Washington, D.C.

Miller, M.F., G. H. Loneragan, D. D. Harris, K. D. Adams, J. C. Brooks, J.C., M. M. Brashears. 2008. Environmental Dust Exposure as a Factor Contributing to an Increase in Escherichia coli O157 and Salmonella Populations on Cattle Hides in Feedyards. *Journal of Food Protection*. 71(10):2078-2081.

Montenegro, M.A., M. Buite T. Trumpf, S. Alksic, G. Reuter, E. Bulling, and R. Helmuth. 1990. Detection and characterization of fecal verotoxin-producing Escherichia coli from healthy cattle. *Journal of Clinical Microbiology*, 28:1417-1421.

Monterey County Agricultural Commissioner's Office. 2009 *2008 Crop Report*. Salinas, CA: Monterey County Agricultural Commissioner's Office. Available at: www.monterey.ca.us/ag

Monterey County Farm Bureau. 2007. Caltrans warns about highway encroachment for food safety. *Farm Focus* (May 2007), p.6.

Monterey County. 2009. *Municipal Code.* Salinas, CA: Monterey County Government. Accessed July 8, 2009 at: http://www.municode.com/resources/gateway.asp?pid=16111&sid=5

Moore, M.T., C.M. Cooper, S. Smith, Jr., E.R. Bennett, R. Schulz, J.L.Farris, F.D. Shields, Jr. 2002. Influence of vegetation in mitigation of methyl parathion runoff. In Proceedings of the 6yh International Conference on Diffuse Pollution, Amsterdam, The Netherlands, IWA Publishing, London, UK.

Morabito, S., G. Dell'Omo, U. Agrimi, H. Schmidt, H. Karch, T. Cheasty, A. Caprioli. 2001. Detection and characterization of shiga toxin-producing *Escherichia coli* in feral pigeons. *Veterinary Microbiology*, 82:275-283.

Moyle, P. B., and J. E. Williams. 1990. Biodiversity loss in the temperate zone: decline of the native fish fauna of California. Conservation Biology 4:275– 284.

Myers, N., R. Mittermeir, C. G. Mittermeir, G. A. B. Da Fonseca, and J. Kent. 2000.Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Nagano, Y., Finn, M., Lowery, C., Murphy, T., Moriarty, J., Power, E., Toolan, D., Oloughlin, A., Watabe, M., Mccorry, K., Crothers, E., Dooley, J., Rao, J., Rooney, P., Millar, B., Matsuda, M., Elborn, J., Moore, J. 2007. Occurrence of Cryptosporidium parvum and bacterial pathogens in faecal material in the red fox (Vulpes vulpes) population. V*eterinary Research Communications* 31, 559-564.

Naiman, R.J., H. Decamps, M. Pollock. 1993. The Role of Riparian Corridors in Maintaining Regional Biodiversity. *Ecological Applications,* 3(2):209-212.

Nataro, J.P and J.B. Kaper. 1998. Diarrheagenic *Escherichia coli. Clinical Microbiology Reviews,* 11:142-201.

Natural Resource Conservation Service. 2006. Elkhorn Slough Watershed Project: 1994-2005 Summary Report. United States Department of Agriculture, Natural Resouce Conservation Service. Salinas, California.

Nicolle, C., N. Cardinault, E. Gueux, L. Jaffrelo, E. Rock, A. Mazur, P. Amouroux, C. Remesy. 2003. Health effect of vegetable-based diet: lettuce consumption improves cholesterol metabolism and antioxidant status in the rat. Clinical Nutrition 23: 605- 614.

Nielsen, E. M., M. N. Skov, J. J. Madsen, J. Lodal, J. B. Jespersen, and D. L. Baggesen. 2004. Verocytotoxin-Producing *Escherichia coli* in Wild Birds and Rodents in Close Proximity to Farms. *Applied and Environmental Microbiology* 70:6944–6947.

Nielsen, E.M., M.N. Skov, J. J. Madsen, J. Lodal, J.B. Jespersen and D.L. Baggesen. 2004 Verocytotoxin-producing Eschericia coli in wild birds and rodents in close proximity to farms. Applied Environmental Microbiology, 70:6944-6947.

NMFS, 2005. Designation of critical habitat for 7 salmon and steelhead ESUs in California. http://swr.nmfs.noaa.gov/chd/Final_CHD_4b2_Report-Aug_05-part_1.pdf

NOAA. National Oceanic and Atmospheric Administration. 1999. Action Plan: Agriculture and Rural Lands, Monterey Bay National Marine Sanctuary. Water Quality Protection Program for Monterey Bay National Marine Sanctuary. Monterey, CA.

Nokes, R.L., C.P. Gerba, M.M. Karpiscak. 2003. Microbial water quality improvement by small scale on-site subsurface wetland treatment. *Journal of Environmental Science and Health Part A-Toxic /Hazardous Substances and Environmental Engineering,* 38(9):1849-1855.

Noss, R. F., E. T. LaRoe III, J. M. Scott. 2001. Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation. Endangered Ecosystems of the United States, USGS Biological Resources. http://el.erdc.usace.army.mil/emrrp/emris/EMRIS_PDF/ec.pdf

NRCS. Natural Resource Conservation Service. 2009. Retrieved from: http://www.nrcs.usda.gov/technical/standards/nhcp.html

Oliver, J., S. Rech , P. Moisander, K. O'Conner and R. Clark. 2009.Evaluating The Possible Role Of Birds And Mammals As Vectors Of Human Pathogenic Microbes From A Gradient Of Wetland Habitat Adjacent To Farms. Proposal submitted to Agricultural and Food Research Programs, USDA grants program.

Olsen, S. J., Miller, G., Breuer, T., Kennedy, M., Higgins, C., Walford, J., McKee, G., Fox, K., Bibb, W. and Mead, P. 2002. A waterborne outbreak of Escherichia coli O157 : H7 infections and hemolytic uremic syndrome: Implications for rural water systems. *Emerging Infectious Diseases,* 8(4): 370-375.

Olson, D. M., and E. Dinerstein. 1998. The Global 200: a representation approach to conserving the earth's most biologically valuable ecoregions. Conservation Biology 12: 502-515.

Osbourne, L.L and D.A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. *Freshwater Biology,* 29(2):243-258.

Paige, C. 2008. A Landowner's Guide to Wildlife Friendly Fences. Landowner/Wildlife Resource Program, Montana Fish, Wildlife and Parks, Helena, MT. 44 pgs.

Palmgreen, H., M. Sellin, S. Bergstrom, B. Olsen. 1997. Enteropathogenic bacteria in migrating birds arriving in Sweden. *Scandanavian Journal of Infectious Diseases,* 29(6):565-568.

Parish, M.E. 1998. Coliforms, *Escherichia coli* and *Salmonella* Serovars associated with a citrus-processing facility implicated in a Salmonellosis outbreak. *Journal of Food Protection*, 61(3):280-284.

Pawiak, R., M. Mazuridewicz, J. Molenda, J. Pinowski, A. Wieliczko. 1991. The occurrence of *Escherichia coli* strains pathogenic to humans and animals in the eggs and nestlings of *Passer* spp. In: Proceedings of International Symposium of the Working Group on Granivorous Birds, INTECOL, September 14-17, 1989. Shipsk, Poland, pgs. 139-151.

Pedersen, K. and L. Clark. 2007. A review of Shiga toxin *Escherichia coli* and *Salmonella enterica* in cattle and free-ranging birds:Potential association and epidemiological links. *Human-Wildlife Conflicts*, 1(1):68-77.

Pedersen, K., L Clark, W.F. Andelt, and M. D. Salman, 2006. Prevalence of Shiga toxin producing *Escherichia Coli* and *Salmonella Enterica* in rock pigeons captured in Fort Collins, Colorado. *Journal of Wildlife Diseases,* 42(1):46–55

Penrod, K, R. Hunter, M. Marrifield. 2001. Missing Linkages: Restoring Connectivity in the California Landscape, Conference Proceedings. Co-sponsored by California Wilderness Coalition, The Nature Conservancy, U.S. Geological Service, Center for Reproduction of Endangered Species, and California State Parks.

Peot, J. 2008. Salads and salad dressings. Prepared Foods. March 1, 2008. Accessed July 2, 2009 at:http://www.preparedfoods.com/Articles/Feature_Article/BNP_GUID_9-5-2006_A_10000000000000274329

Pomeroy, R., and R. Rivera-Guieb. 2005. *Fishery Co-Management: A Practical Handbook.* Cambridge, MA: CAB International and International Development Research Centre.

Potter, K.W. 1994. Estimating potential reduction flood benefits of restored wetlands. *Water Resources Update*, 97:34-38.

Primack, R. 2008. *A Primer of Conservation Biology* (4th Edition). Sunderland, MA: Sinauer Associates.

Produce Safety Project. 2009. Comparison of GAPs Governing the Growing and Harvesting of Fresh Produce. Washington, DC: Georgetown University Produce Safety Project.

Queheillalt, D.M. and M.L. Morrison. 2006. Vertebrate Use of a Restored Riparian Site: A Case Study on the Central Coast of California. *Journal of Wildlife Management* 70(3):859-866.

Rangel, J. M., P. H. Sparling, *et al.* 2005. Epidemiology of Escherichia coli O157: H7 outbreaks, United States, 1982-2002. *Emerging Infectious Diseases* 11(4): 603-609.

Rathbun, G.B., N.J. Scott, Jr., and T.G. Murphy. 1997. *Rana aurora draytonii* (California red-legged frog). Behavior. *Herpetological Review,* 28:85-86.

Reinstein, S., J.T. Fox, X. Shi, M.J. Alam, D.G. Renter and T.G. Nagaraja. 2009. Prevalence of *Escherichia coli* O157:H7 in organically and naturally raised beef cattle. *Applied and Environmental Microbiology.* 75(16):5421-5423.

Renter, D.G., D.P. Gnad, J.M. Sargeant and S.E. Hygnstorm. 2006. Prevalence and serovars of *Salmonella* in the feces of free-ranging white-tailed deer (Odocoileus virginianus) in Nebraska. *Journal of Wildlife Diseases,* 42(3):699-703.

Renter, D.G., J.G. Morris, J.M. Sargeant, L.L. Hungerford, J. Berezowski, T. Ngo, K. Williams, and D.W.K. Acheson. 2005. Prevalence, risk factors, O serogroups, and virulence profiles of Shiga toxin-producing bacteria from cattle production environments *Journal of Food Protection,* 68(8):1556-1565.

Renter, D.G., J. M. Sargeant and L.L. Hungerford. 2004. Distribution of *Escherichia coli* O157 : H7 within and among cattle operations in pasture-based agricultural areas. *American Journal of Veterinary Research,* 65(10):1367-1376.

Renter, D.G., J.M. Sargeant, R.D. Oberst and M. Samadpour. 2003. Diversity, frequency, and persistence of *Escherichia coli* O157 strains from range cattle environments. *Applied and Environmental Microbiology,* 69(1):542-547.

Renter, D.G., J.M. Sargeant, S.E. Hygnstorm, J.D. Hoffman, J.R. Gillespie. 2001. Escherichia coli O157:H7 in free-ranging deer in Nebraska. *Journal of Wildlife Diseases,* 37(4):755-760.

Resource Conservation District. 2007. A Grower Survey: Reconciling Food Safety and Environmental Protection. Salinas, CA: Resource Conservation District of Monterey County.

Resource Conservation District. 2009. Challenges to Co-Management for Food Safety and Environmental Protection: A Grower Survey. Salinas, CA: Resource Conservation District of Monterey County.

Rice, D. H., Hancock, D. D. and Besser, I. E. 2003. Faecal culture of wild animals for Escherichia coli O157:H7. *Veterinary Record,* 152(3):82-83.

Richards J. M., B.A., J. D. Brown, T. R. Kelly, A. L. Fountain, J. M. Sleeman. (2004). Absence of detectable *Salmonella* cloacal shedding in free-living reptiles on admission to the wildlife center of Virginia. *Journal of Zoo and Wildlife Medicine* 35(4): 562–563

Roberts, P. 2009. The End of Food. New York: Houghton Mifflin.

Rundio, D.E. and S.T. Lindley. 2008. Seasonal Patterns of Terrestrial and Aquatic Prey Abundance and Use by Oncorhynchus mykiss in a California Coastal Basin with a Mediterranean Climate. *Transactions of the American Fisheries Society* 137:467–480, 2008.

Sacks, A. 2008. Live frog in lettuce stuns mom. *New York Daily News*, Jan. 24, 2008. Accessed online June 25, 2009 http://www.nydailynews.com/news/2008/01/24/2008-01-24_live_frog_in_lettuce_stuns_mom.html.

Salmon, T. 2008. Rodents, rodent control and food safety. Proceedings of 23rd Vertebrate Pest Conferece, University of California, Davis. 16-19.

Salomone, K, Greenberg, M., Sandman, P. and D. Sachsman. 1990. Science and the News: A Question of Quality How Journalists and News Sources Evaluate Coverage of Environmental Risk. *Journal of Communication* 40(4):117-130.

Samadpour, M., J. Stewart, K. Steingard, C. Addy, J. Louderback, M. McGin, J. Ellington, T. Newman. 2002. Laboratory investigation of an *E. coli* O157:H7 outbreak associated with swimming in Battle Ground Lake, Vancouver, Washington. *Journal of Environmental Health*, 64(10):16-20.

Sanchez, S., A. Garcia-Sanchez, R. Martinez, J. Blanco, J.E. Blanco, M. Blanco, G. Dahbi, A. Mora, J. Hermoso de Mendoza, J.M. Alonso, J. Rey. 2009. Detection and characterization of Shiga-producing *Escherichia coli* other than *Escherichia coli* O157:H7 in wild ruminants. *Veterinary Journal*, 180: 384-388.

Sanderson, M. W., Sargeant, J. M., Shi, X. R., Nagaraja, T. G., Zurek, L. and Alam, M. J. 2006. Longitudinal emergence and distribution of Escherichia coli O157 genotypes in a beef feedlot. *Applied and Environmental Microbiology*, 72(12):7614-7619.

Sandman, P. 1999. Risk = Hazard + Outrage: Coping with Controversy about Utility Risks. *Engineering News-Record*, October 4, pp. A19–A23.

Sandman, P. 2007. Avian Flu, a Pandemic & the Role of Journalists. *Nieman Reports* (Spring 2007). Cambridge, MA: The Nieman Foundation for Journalism at Harvard University.

Sargeant, J.M., D.J. Hafer, J.R. Gillespie, R.D. Oberst, S.J. Flood. 1999. Prevalence of *Escherichia coli* O157:H7 in white-tailed deer sharing rangeland with cattle. *Journal of the American Veterinary Medical Association*, 215(6): 792-794.

Schaafsma, J.A., A.H. Baldwin and C. A. Streb. 2000. AN evaluation of a constructed wetland to treat wastewater from a dairy farm in Maryland, USA. *Ecological Engineering*, 14(1-2):199-206.

Schaife, H.R., D. Cowan, J. Finney, S.F. Kinghorn-Perry, B. Crook. 2006. Wild rabbits (Oryctolagus cuniculus) as potential carriers of verocytotoxin-producing *Escherichia coli Veterinary Record*, 159(6):175-178.

Schmit, J. 2006. 'Fresh Express Leads the Pack' in Produce Safety. *USA Today*, October 23, 2006. online 10/01/09 at http://www.usatoday.com/money/industries/food/2006-10-22-fresh-express-usat_x.htm

Schoeltens, R.T. and G. Caroli. 1971. Role of pigeons in the spread of salmoneliosis: Incidence of different types of *Salmonella typhi-murium* var. *copenhagen* in pigeons, man and other animals. *Antonie van Leeuwenhoek*, 37:473-476.

Servia, M.J. A.R.R. Péry, M. Heydorff, J. Garric and L. Lagadic. 2006. Effects of copper on energy metabolism and larval development in the midge *Chironomus riparius*. *Ecotoxicology* 15:229-240.

Seymour, R. B. and M.F. Westphal. 2000. Regional distribution of declining anuran, Rana aurora draytonii, on the San Francisco Peninsula, California, USA. Poster Presentation 80th Annual Meeting of the American Society of Ichthyologists and Herpetologists in La Paz, Mexico on June 16, 2000.

Seymour, R., M.F. Westphal, A. E. Launer. 2007. Report on 2006 surveys for sensitive amphibian and reptile species on lands of the Midpeninsula Regional Open Space District. Prepared by Richard B. Seymour and Associates for Midpeninsula Regional Open Space District, June 30, 2007.

Shere JA, Bartlett KJ & Kaspar CW. 1998. Longitudinal study of Escherichia coli O157:H7 dissemination on four dairy farms in Wisconsin. *Applied and Environmental Microbiology* 64:1390-1399.

Sivapalasingam, S., C. R. Friedman, *et al.* 2004. Fresh produce: A growing cause of outbreaks of foodborne illness in the United States, 1973 through 1997. *Journal of Food Protection* 67(10): 2342-2353.

Smith, J. J. 2002. Habitat conditions and steelhead in the Arroyo Leon seasonal reservoirs and adjacent stream in 2001. Department of Biological Services, San Jose State University, San Jose, CA, May 18, 2002.

Solomon, E.B., C.J. Potenski *et al.* 2002. Effect of irrigation method on transmission to and persistence of *Escherichia coli* O157:H7 on lettuce. *Journal of Food Protection,* 65(4):673-676.

Soulé, M. 2001. Is Connectivity Necessary? In: Penrod, K, *et al.*. Missing Linkages: Restoring Connectivity in the California Landscape, Conference Proceedings. Co-sponsored by California Wilderness Coalition, The Nature Conservancy, U.S. Geological Service, Center for Reproduction of Endangered Species, and California State Parks. 2001.

Sprotsen, E.L., M. Macrae, I.D. Ogden, M.J. Wilson, N.J.C. Strachan. 2006. Slugs: Potential novel vectors of *Escherichia coli* O157. *Applied and Environmental Microbiology,* 72(1):144-149.

Srikantiah, P., Lay, J. C., Hand, S., Crump, J. A., Campbell, J., Van Duyne, M. S., Bishop, R., Middendor, R., Currier, M., Mead, P. S. and Molbak, K. 2004. *Salmonella* enterica serotype Javiana infections associated with amphibian contact, Mississippi, 2001. *Epidemiology and Infection,* 132(2):273-281.

State of California. 1997. Department of Conservation, Farmland Mapping and Monitoring Program. Sacramento, CA.

Stearns, D. 2006. A Future Uncertain: Food Irradiation from a Legal Perspective. Pages 263-278, In: C.Sommers and X. Fan (editors), *Food Irradiation Research and Technology.* Hoboken, NJ: Blackwell Publishing and Institute of Food Technologists Press.

Steinmetz, K.A., and J.D. Potter. 1996. Vegetables, fruit, and cancer prevention: a review. *Journal of the American Dietetic Association.* 96:1027- 1039.

Stone, W. B., J.C. Okoniewski, J. R. Stedelin. 1999. Poisoning of wildlife with anticoagulant rodenticides in New York. *Journal of Wildlife Diseases Volume:* 35(2): 187-193.

Stuart, D. 2008. The Illusion of Control: Industrialized Agriculture, Nature, and Food Safety. *Agriculture and Human Values* 25:177–181

Stuart, D. 2009a. Constrained Choice and Ethical Dilemmas in Land Management: Environmental Quality and Food Safety in California. *Journal of Agricultural and Environmental Ethics,* 22:53-71.

Stuart, D. 2009b. *A new wave of environmental degradation in California agriculture: private standards, constrained choice, and changes in land management.* Doctoral Dissertation. University of California, Santa Cruz.

Su, L.J., and L. Arab. 2006. Salad and raw vegetable consumption and nutritional status in the adult US population: results from the third national health and nutrition examination survey. *Journal of the American Dietetic Association.*106:1394.

Suslow, T. 2003. Key Points of Control and Management of Microbial Food Safety: Information for Growers, Packers and Handlers of Fresh-Consumed Horticultural Products. Regents of the University of California, Bulletin Publication 8102.

Swaim Biological, Inc. 2007. Results of surveys for the San Francisco garter snake at Milagra Ridge and Rancho Corral De Tierra for Golden Gate National Recreation Area, San Mateo County, California. Final Report. Prepared for Golden Gate National Recreation Area. 28 pg.

Swedberg, C. 2009. Calfironia Polytechnic Studies E.coli and Bagged Greens. *RFID Journal.* Accessed online: http://www.rfidjournal.com/article/print/5290

Symonds, K. 2008. Rancher restore amphibian-friendly ponds. *Endangered Species Bulletin,* Spring 2008, 30-31.

Syversen, N. and M. Bechmann. 2004. Vegetative buffer zones as pesticide filters for simulated surface runoff. *Ecological Engineering,* 22(3): 175-184.

Szalanski, A.L., C. B. Owens, T. McKay, C. D. Steelman 2004. Detection of Campylobacter and Escherichia coli O157:H7 from filth flies by polymerase chain reaction. *Medical and Veterinary Entomology.* 18(3):241-246.

Takeuchi, K. and J.F. Frank. 2000. Penetration of *Escherichia coli* O157:H7 into lettuce tissues as affected by inoculum size and temperature and the effect of chlorine treatment on cell viability. *Journal of Food Protection,* 63:434-440.

Talley, J.L., A.C. Wayadande, L.P. Wasala, A.C.Gerry, J.Fletcher,U. DeSilva, S.E. Gilliland. 2009. Association of Escherichia coli O157:H7 with Filth Flies (Muscidae and Calliphoridae) Captured in Leafy Greens Fields and Experimental Transmission of *E. coli* O157:H7 to Spinach Leaves by House Flies (Diptera: Muscidae). *Journal of Food Protection,* 72(7):1547-1552.

Tate, K.W., Atwill, E.R., Bartolome, J.W., and Nader, G.A. 2006. Significant *Escherichia coli* Attenuation by Vegetative Buffers on Annual Grasslands. *Journal of Environmental Quality,* 35:795-805.

Tauxe, R. V. 1997. Emerging foodborne diseases: An evolving public health challenge. *Emerging Infectious Diseases* 3(4): 425-434.

The Nature Conservancy. 2006. California Central Coast Ecoregional Plan Update. October 2006. Accessed online: conserveonline.org/library/California%20Central%20Coast%20Ecoregional%20Plan%20Update

Thompson, L.C., J.L. Voss, R. E. Larsen, W.D. Tietje, R.A. Cooper and P.B. Moyle. 2006. Role of hardwood in forming habitat for southern California steelhead. Presented at Sixth California Oak Symposium: Today's Challenges, Tomorrow's Opportunities, October 9-12, 2006. Rohnert Park, CA.

Trochim, W. (2000). *The Research Methods Knowledge Base, 2nd Edition.* Atomic Dog Publishing, Cincinnati, OH.

U.S. Department of Agriculture. 2007. *USDA National Organic Program Standards.* 7 CFR, Part 205.

U.S. EPA, 1994. Copper Sulfate. Extension Toxicology Network. Pesticide Information Project, Extension Offices of Cornell University, Michigan State University, Oregon State University and University of California, Davis. Retrieved at http://extoxnet.orst.edu/pips/coppersu.htm

U.S. Government. 2008. Irradiation in the Production, Processing and Handling of Food. (August 28) Federal Register 73(164):49593-49603. Washington DC: Department of Health and Human Services, Food and Drug Administration.

United States Census of Agriculture. 2007. Accessed online: http://www.nass.usda.gov/Census_of_Agriculture/index.asp.

United States Department of Agriculture/Animal and Plant Health Inspection Service. 1997. An Update: *Escherichia coli O157:H7* in Humans and Cattle. Centers for Epidemiology and Animal Health. http://www.aphis.usda.gov/vs/ceah/cei/taf/emerginganimalhealthissues_files/ecoupdat.pdf

United States Environmental Protection Agency (U.S. EPA). 2006. Rodenticide Incidents Update (November 15, 2006). Washington, D.C.: Office of Prevention, Pesticides, and Toxic Substances.

United States Environmental Protection Agency (U.S. EPA). 2007. Retrieved from: http://oaspub.epa.gov/tmdl/enviro.control?p_list_id=CAE306%2E000ELKHORN%20SLOUGH

United States Environmental Protection Agency (U.S. EPA). 2008. Risk Mitigation Decision for Ten Rodenticides (May 28, 2008). Washington, D.C.: Office of Prevention, Pesticides, and Toxic Substances.

U.S. Fish and Wildlife Service. 2002. Recovery plan for the California red-legged frog (*Rana aurora draytonii*). U.S. Fish and Wildlife Service, Portland, Oregon. 173 pg.

United States Geological Survey (USGS). 2009. Retrieved from: http://water.usgs.gov/nawqa/nutrients/pubs/wcp_v39_no12/

United States Government 2009. President Barack Obama Announces Key FDA Appointments and Tougher Food Safety Measures. Washington DC: The White House, Office of the Press Secretary, March 14.

University of California (UC) Agricultural Issues Center 2007. Statistical Overview of California's Organic Agriculture 2000 – 2005. May 2007. Accessed online: aic.ucdavis.edu/publications/Statistical_Review_00-05.pdf

Urban, J.E. and A. Broce. 1998. Flies and their bacterial loads in greyhound dog kennels in Kansas. *Current Microbiology.* 36 (3):164-170.

US Army Corps of Engineers. 2008. Public Notice # 08-00441. San Francisco, CA: Regulatory Division, San Francisco District (November 26).

USDA/APHIS United States Department of Agriculture/Animal and Plant Health Inspection Services. 2003. *Salmonella* and *Campylobacter* on U.S. Dairy Operations. Accessed June 10, 2009 at http://www.aphis.usda.gov/vs/ceah/ncahs/nahms/dairy/dairy02/Dairy02SalCampy.pdf

Van Dijk, P. M., F. Kwaad, and M. Klapwijk. 1996. Retention of water and sediment by grass strips. *Hydrological Processes,* 10(8):1069-1080.

van Hullebusch, E., P. Chatenet, V Deluchat, P. M. Chazal, D. Froissard, M. Botineau, A. Chestem, M. Baudu. 2003. Copper Accumulation in a Reservoir Ecosystem Following Copper Sulfate Treatment (St. Germain Les Belles, France). *Water, Soil and Air Pollution,* 150:3-22.

Wachtel, M.R., L. C. Whitehand and R.E. Mandrell. 2002. Association of *Escherichia coli* O157:H7 with Preharvest Leaf Lettuce upon Exposure to Contaminated Irrigation Water. *Journal of Food Protection,* 65(1):18-25.

Wachtel, M.R., L. C. Whitehand and R.E. Mandrell. 2002b. Prevalence of *Escherichia coli* O157:H7 Associated with a Cabbage Crop Inadvertently Irrigated with Partially Treated Sewage Wastewater. *Journal of Food Protection,* 65(3):471-475

Wada, Y., H. Kondo, M. Nakazawa, M. Kubo. 1995. Natural infection with attaching and effacing Escherichia coli and adenovirus in the intestine of a pigeon with diarrhea. *Journal of Veterinary Medical Science,* 57:531-533.

Wahlstrom, H., E. Tysen, E. Olsson Engvall, B. Brandstrom, E. Eriksson, T. Morner, I. Vagsholm. Survey of Campylobacter species, VTEC O157 and *Salmonella* species in Swedish wildlife. *Veterinary Record,* 153(3):74-80.

Waithman, J.D., R. A. Sweitzer, D. Van Vuren, J.D. Drew, A.J. Brinkhaus, I.A. Gardner, and W.M. Boyce. 1999. Range expansion, population sizes, and management of wild pigs in California. *Journal of Wildlife Management,* 63(1):298-308.

Wallace, J.S., Cheasty, T, and K. Jones. 1997. Isolation of Vero cytotoxin producing Escherichia coli O157 from wild birds. *Journal of Applied Microbiology*. 82: 399- 404.

Wang, G., T. Zhao and M. P. Doyle. 1996. The fate of Enterohemorrhagic *Escherichia coli* O157:H7 in Bovine Feces. *Applied and Environmental Microbiology*, 62(7):2567-2579.

Weise, J. and J. Schmit. 2007. Spinach recall: 5 faces, 5 agonizing deaths, 1 year later. Last Year Five People Died From an *E. coli* Outbreak. What Has Changed Since Then? *USA Today*. Sept 20, 2007.

Wells, S. J., P.J. Fedorica-Cray, D.A. Dargatz, K. Ferris and A. Green. 2001. Fecal shedding of *Salmonella* spp. by dairy cows on farm at at cull cow markets. *Journal of Food Protection*. 64:3-11. http://nahms.aphis.usda.gov/dairy/dairy96/ecosalm98.pdf

Wells, J.E., Berry, E.D. and Varel, V.H. 2005. Effects of common forage phenolic acids on Escherichia coli O157:H7 viability in bovine feces. *Appl. and Environ. Microbiol.* 71: 7974–7979.

Westphal, M. and R. Seymour, 1998. Results of amphibian surveys at Higgins Creek Reservoirs on Arroyo Leon near Half Moon Bay, San Mateo County, August 1998 Report to San Mateo County Resource Conservation District.

Whyte, P., J.D. Collins, *et al.* (2001) "Distribution and prevalence of airborne microorganisms in three commercial poultry processing plants." *Journal of Food Protection* 64(3):388-391.

Wilson, D., Nielsen, J. and P.Degnbol (eds.), 2003. *The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects.* New York: Springer.

Witmer, G. W., R. B. Sanders, and A. C. Taft. 2003. Feral swine- are they a disease threat to livestock in the US? In: Proceedings of the 10th Annual Wildlife Damage Management Conference.

Wolinsky, S. 2005. Farm Pond Ecosystems. Fish and Wildlife Habitat Management Leaflet. Number 29. Wildlife Habitat Management Institute.

Woltemade, C.J. 2000. Ability of restored wetlands to reduce nitrogen and phosphorus concentrations in agricultural drainage water. *Journal of Soil and Water Conservation*, 55(3):303-309.

Wood, S.L.R. and J. S. Richardson. 2009. Impact of sediment and nutrient inputs on growth and survival of tadpoles of the Western Toad. *Freshwater Biology*, 54:1120-1134.

Worldwatch Institute. 2008. *State of the World 2008: Toward a Sustainable Global Economy*. Washington DC: The Worldwatch Institute.

Wray, C. and R.H. Davies. 2000. *Salmonella* infection in cattle. In: *Salmonella* in Domestic Animals (C. Wray and A. Wray Eds), CABI, New York, NY., 169-190.

Wright, R.T. 2007. *Environmental Science: Toward a Sustainable Future (10th Edition)*. Prentice Hall.

Yan, T., M. Hamilton, and M. J. Sadowsky. 2007. High throughput and quantitative procedure for determining sources of *Escherichia coli* in waterways using host-specific DNA marker genes. Appl. Environ. Microbiol. 73:890–896.

Yilmaz, A., H. Gun, and H. Yilmaz. 2002. Frequency of *Escherichia coli* O157:H7 in Turkish cattle. *Journal of Food Protection*, 65:1637-1640.

Zedler, J.B. 2003. Wetlands at your service: Reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and the Environment*, 1(2):65-72.

Zschock, M., H.P. Harmann, B. Kloppert, and W. Wolter. 2000. Shiga-toxin-producing *Escherichia coli* in feces of healthy dairy cows, sheep and goats: Prevalence and virulence properties. *Letters in Applied Microbiology*, 31:203-208.

## Appendix A. Supplemental Background Information

### Central Coast Agricultural Sector

About Monterey County

- Of all the counties in California and in the U.S., Monterey County is the top producer of lettuce (U.S. Census of Agriculture 2007).
- Monterey County produces 63% of the lettuce and 91% of the salad greens grown in California (CA Agricultural Resources Directory 2009). Monterey County contains the Salinas Valley, known as the "Salad Bowl of America".
- The climate is ideal for long growing seasons: for example, iceberg lettuce can be harvested April through October (ERS 2001).
- In addition to lettuce, Monterey County is also a top producer of other commodities, producing 44% of broccoli, 37% of strawberries, 81% of artichokes, 63% of spinach, and 44% of cabbage grown in California (CA Agricultural Resources Directory 2009).
- In 2007, there were approximately 1,200 farms in the county covering over 1.3 million acres of land (U.S. Census of Agriculture 2007).
- In 2008, Monterey County reported an agricultural production value of $3.82 billion with lettuce production alone producing over $1.1 billion in gross value (CA Agricultural Resources Directory 2009, Monterey County Agricultural Commissioner's Office 2009).

Other Central Coast Counties

- While Monterey County produces the majority of lettuce and leafy greens in California, other counties in the Central Coast region are also important agricultural producers.
- San Benito County produces many vegetable crops including 8% of spinach and 4% of lettuce in California (CA Agricultural Resources Directory 2009).
- Santa Cruz and San Mateo counties have over 9,000 acres planted in a diversity of vegetable crops including lettuce and leafy greens. The two counties are the top producers of Brussels sprouts in California.
- San Luis Obispo and Santa Barbara counties are both major producers of broccoli, strawberries, and wine grapes but growers in these counties also produce lettuce and other leafy greens.

Diversified Agriculture Industry

- The agricultural industry in the Central Coast region is diverse in many ways. Due to the diversity of local microclimates, the region is able to produce over 200 different agricultural crops.
- Growers in the region are also diverse with both small and large-scale operations as well as organic and conventional production. According the U.S. Census of Agriculture (2007) approximately 20 percent of growers in Monterey County operate less than 10 acres while another 20 percent operate over 1,000 acres. The average farm size in Monterey County is 1,108 acres (U.S. Census of Agriculture 2007).

- Organic production is growing in the region with over 13% of all Central Coast growers producing organic products in 2005 and farm receipts of approximately $1.5 billion (UC Agricultural Issues Center 2007).
- Approximately 40% of growers in the region lease their land (U.S. Census of Agriculture 2007).
- Many growers have contracts to sell to shippers (who sell commodities to retailers) or processors (who process foods and sell value-added goods to retailers, such as bagged ready-to-eat salads). Other growers operate as both growers and shippers with contracts to sell to food retailers. Retailers include grocery stores, restaurants, and food service companies.
- In some cases large processors or shippers own land that they contract with growers to cultivate. Each grower may have different specifications in their production contracts regarding who pays for upfront costs and inputs and expectations regarding crop quality, harvest, and payment.
- In many cases there is considerable competition between growers to garner contracts with the largest shippers or processors who account for a significant portion of market share. Due to the interconnected and competitive nature of the produce sector, decisions made by retail, shipping, and processing firms can impact business conditions for other firms as well as produce production and the income of regional growers.

The Importance of Bagged Salads

- With the rising popularity of bagged salads, processors play an increasingly important role in Central Coast agriculture. Washed and bagged leafy greens as well as chopped salad blends and kits have become lucrative value-added products in the produce sector (ERS 2001, Mintel 2008, Shaw 2008).
- Baby greens and lettuce mixes were once considered a delicacy found at fine restaurants. Due to innovations in the late 1980's, bagged salads became the second biggest selling item in U.S. grocery stores, reaching $2.5 billion in annual sales (Consumer Reports 2006).
- Sales of bagged salads increased approximately 560% between 1993 and 1999 (ERS 2001), 42% between 2001 and 2006 and are predicted to rise an additional 38% from 2007 through 2011 (Peot 2008).
- The largest bagged salad processors in the U.S. are Fresh Express, Dole, and Taylor Farms, which together control the vast majority of the bagged salad industry. Processing companies have headquarters and processing plants located in the Central Coast region, and have production contracts with area growers.

## Ecological Attributes of the California's Central Coast Region

Economic Contribution

- The region's natural resource endowment drives a significant part of the economy through tourism in a variety of forms (general tourism, nature tourism, agro-tourism).
- The natural resources also provide multiple types of "ecosystem services" that contribute economically to the region and maintain the high quality of life.
- Resource economists have recently begun to calculate the total dollar value of ecosystem services on local and global scales. Central Coast ecosystems provide more than two dozen types of goods and services, parts of which can reasonably be expected to be lost in the absence of conservation efforts. They include:

- *Provisioning Services:* Safe drinking water (naturally purified in aquifers & wetlands); clean air (cycled by plants), fuelwood for fireplaces & stoves, genetic resources for creating new medicines, wild foods (mushrooms, berries), hunting opportunities, and many other benefits
- *Regulating Services:* Wetlands minimize flood damage, hillside vegetation reduces risk of mud slides, bees provide pollination, nutrient cycling via decomposers, erosion prevention, climate regulation, disease regulation, decomposition of wastes, pest control from beneficial insects, raptors, etc.., hedgerows and windbreaks reduce pesticide drift, and many other benefits.
- *Cultural Services:* Recreation and tourism (local and non-local visitors), aesthetic values (open space, nice views, sense of beauty), social benefits (place for picnics, walks, family outings), sense of place (what your "home" looks & feels like), religious use (church gatherings / worship), educational values (summer camps for kids), inspiration (for painters, sculptors, musicians and others), existence value (knowing that eagles, condors, frogs, and other life forms exist even if you do not experience them directly), physical well-being (places to jog, run, walk), emotional well-being (relaxed rural setting compared to city)

- Ecosystem contributions are often overlooked, without them society would be forced to find expensive alternatives to these services.
- Central Coast ecosystems tend to be large and complex, but protecting them consists of small, specific steps. A farmer does not set out to maintain an ecosystem *per se,* but rather plants a hedgerow, keeps a wetland, or takes any number of other small steps that have larger impacts when aggregated across a landscape.

Ecological Features

- The Central Coast ecoregion has been identified by scientists as an "ecological hotspot" based on species richness and identified threats to biodiversity (Olson *et al.* 1998, Myers *et al.* 2000).
- The Central Coast provides essential habitat for many rare species, including, Steelhead trout (federally listed as Threatened), California red-legged frog (federally listed as Threatened), the California tiger salamander (federally listed as Endangered in Sonoma and Santa Barbara Counties. Threatened throughout the rest of the range), and the San Francisco garter snake (federally listed as Endangered). According to the California Department of Fish and Game, the Central Coast region is home to more than 80 species that are listed as endangered, threatened, or rare.[1]
- Central Coast watersheds drain to 29 Marine Protected Areas (MPAs) newly approved by the California Fish and Game Commission, representing 204 square miles of protected marine waters. Additionally, the Central Coast ocean waters are protected by a suite of other marine management designations, including the Monterey Bay National Marine Sanctuary and multiple Critical Coastal Areas and Areas of Special Biological Significance. (http://www.sanctuarysimon.org/monterey/sections/reserves/index.php).
- The Monterey Bay National Marine Sanctuary is home to one of the last populations of the endangered Southern Sea Otter (*Enyhdra lutris nereis*), federally listed as Threatened.
- The Central Coast region also contains Elkhorn Slough, one of the largest remaining salt marsh wetlands, providing vital habitat for fish and bird species (Caffrey *et al.* 2002).

[1] Complete species list available at: http://ceres.ca.gov/planning/conservation_guidebook/Central_ESA.pdf

Ongoing Environmental Challenges

- Regional wildlife are increasingly threatened by expanding development, invasive species, water pollution, the alteration of waterways, and climate change (TNC 2006, CWC 2002).
- Natural ecosystems can be significantly impacted by degraded water quality. Agricultural and urban run-off impairs several of the major waterways in the Central Coast region. Three of the major watersheds are the Pajaro River, the Salinas River, and the Elkhorn Slough (NOAA 1999). Approximately 75% of the land surrounding these watersheds is used for agricultural production (State of California 1997). The waterways emptying into the Monterey Bay National Marine Sanctuary repeatedly fail to meet water quality standards with significantly elevated levels of nutrients, pesticides, and sediment (Caffrey 2001, Hunt *et al.* 1999).[2]
- Monitoring in Elkhorn Slough indicates excessive nitrogen loads and erosion due to row crop agriculture (Caffrey *et al.* 2002, Los Huertos *et al.* 2001).
- While there are also urban sources of non-point source pollution in the Central Coast region, agricultural land use has been directly linked with elevated nutrients as well as microbial and organic contaminants in coastal waters (Handler *et al.* 2006).

## Central Coast Contributions to Local and National Public Health

Provider of Fresh Produce

- Consumers have become increasingly aware of linkages between food choices and health and are more commonly selecting foods based on nutritional value and caloric intake (Goldman 2003).
- Salad consumers have been shown to have higher intakes of vitamin C, vitamin E, folic acid, and carotenoids (important antioxidants) (Su *et al.* 2006).
- Numerous studies indicate that diets high in fresh fruits and vegetables are linked with decreased risks of cancer (Steinmetz and Potter 1996).
- A U.S. Department of Agriculture survey conducted in the mid-1990s indicated that lettuce is the number one produce item consumed by U.S. adults, with 40% of the survey population consuming lettuce over a two day survey period (Johnston *et al.* 2000).
- Some scientists suggest that increasing fruit and vegetable consumption in household diets can reduce the intake of fats and sugars and therefore reduce the chances of obesity and type II diabetes (Epstein *et al.* 2001). According to the Center for Disease Control (2009), 34% of the U.S. population is considered obese. Up to 95% of current diabetes cases have been diagnosed as Type II diabetes, which in many cases is linked to obesity.
- Studies indicate lettuce consumption can reduce cholesterol and enhance antioxidant status (due to high levels of vitamin C, vitamin E, and carotenoids) and scientists suggested regular consumption may reduce cardiovascular disease (Nicolle *et al.* 2004).

[2] The Salinas River only reaches the ocean during part of the year, depending on rainfall and water releases from upstream dams.

Outbreaks of Foodborne Illness Associated with Fresh Produce

- Produce-associated outbreaks accounted for 0.7% of all reported foodborne outbreaks in the 1970s, but accounted for 6% in the 1990s (Sivapalasingam *et al.* 2004). This rise may be attributed to several factors including the increase in consumption of raw fruits and vegetables (Bureau of Census 1996, Beuchat 1996), increased reporting of illness and outbreaks (and significantly improved state and federal government capacity to identify them), changes in human demography, microbial adaptation (Altekruse *et al.* 1997), and/or changes in farming or processing practices (Beuchat 2002).

- Produce can become contaminated with a variety of pathogens including *Salmonella spp.* and *Escherichia coli* O157:H7 (*E. coli* O157:H7).

- The 2006 outbreak of *E. coli* O157:H7 associated with bagged spinach brought increasing attention to this particularly virulent strain of E. coli. *E. coli* O157:H7 comes from an animal "reservoir" and can be transmitted onto food through contact with animal feces (Tauxe 1997).

- Each year in the United States an estimated 73,480 illnesses occur from *E. coli* O157:H7 resulting in 2,170 hospitalizations and 61 deaths (Mead *et al.* 1999. Only a portion of these illnesses are reported.

- Most outbreaks are traced to the consumption of contaminated meat, which is often contaminated during the slaughtering process. Consumption of ground beef is the most common vehicle of food borne *E. coli O157:H7* outbreaks: 41 percent of food borne outbreaks are from ground beef, whereas 21 percent are from produce (Rangel *et al.* 2005).

- An estimated 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).

- Foodborne illness concern peaked in the Central Coast region following the 2006 spinach outbreak. It was not the first time the region was linked to *E. coli* O157:H7 outbreaks: of the 10 outbreaks of *E. coli* O157:H7 since 1995 linked to spinach and lettuce, 8 have been traced back to the Central Coast Region (CIDRAP 2007).

- The region is the largest producer of leafy greens and production has been expanding, sometimes into regions near livestock operations and wildlife habitat (Roberts 2008).

Public Health and the Environment

- Adoption of intensive agricultural practices in the U.S. has significantly impaired water quality and can negatively impact human health. Agriculture is the largest single contributor of non-point source water pollution in the U.S.: agriculture contributes to 70% of impaired rivers, 49% of impaired lakes, and 27% of impaired estuaries (U.S. EPA 2000).

- Studies show that approximately 60% of coastal rivers and bays in the U.S. have been degraded specifically by nutrient pollution, and agriculture remains the major source of nutrient deposition in the U.S. (Howarth *et al.* 2002).

- Over 20 waterways in the region are listed as impaired for one or more contaminants by the EPA including the Salinas River, the Santa Maria River, and Corralitos Creek. Primary contaminants include fecal coliforms, pesticides, and nutrients (EPA 2009).

- Recent monitoring of regional surface waters by Central Coast Water Quality Preservation indicate that the majority of Salinas Valley test sites and others in the Central Coast region are well over the EPA nitrate standard of 10 ppm.
- Waterways flowing into the Monterey Bay National Marine Sanctuary repeatedly fail to meet water quality standards with significantly elevated levels of nutrients, pesticides, and sediment (Conley *et al.* 2008, Caffrey *et al.* 2001, Hunt *et al.* 1999).

## Regulations for Food Safety

Food Safety: The California Leafy Greens Products Handler Marketing Agreement (LGMA)

- The California Leafy Greens Products Handler Marketing Agreement (LGMA) was created in 2007 and oversight was granted to the U.S. Department of Agriculture and the California Department of Food and Agriculture (CDFA).
- Signing the marketing agreement is voluntary for handlers of leafy greens. Leafy greens include arugula, butter lettuce, chard, escarole, iceberg lettuce, red leaf lettuce, spinach, baby leaf lettuce, cabbage, endive, green leaf lettuce, kale, romaine lettuce, and spring mix.
- The term "handler" refers to firms responsible for bringing produce to retailers and other produce buyers. Approximately 120 handlers have signed the LGMA that together represent over 99% of the leafy greens produced in the state (LGMA 2009).
- Handlers who sign the Agreement are required to purchase or source their leafy greens produce only from fields which are managed in accordance with a specific set of strict in-field food safety requirements. The requirements, commonly known as "metrics," are detailed in the *Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens* (LGMA 2009).
- LGMA metrics were developed by technical staff and scientists in the produce industry with some input from government agencies and natural resource organizations.
- Growers who do business with signatories of the LGMA are subject to audits that are performed by the California Department of Food and Agriculture (CDFA) inspectors trained by the U.S. Department of Agriculture (USDA).

Food Safety: Private, Corporate Food Safety Programs

- In addition to the LGMA, private produce firms, including shippers, processors, and retailers, developed new measures for food safety following the 2006 spinach outbreak.
- Almost all processors and retailers already had their own food safety standards in place prior to the 2006 outbreak. These standards involve protocols for growing, harvesting, processing, shipping, and storage.
- Most of these standards are considered proprietary information as part of the contracts between growers, handlers, and retailers.
- After the spinach outbreak many of these standards were modified, aiming to further reduce chances of crop contamination and address public concern regarding the safety of fresh produce.

- Several factors drive the development of these individual corporate food safety programs. For example, private firms face pressure to avoid litigation following outbreaks, and even single contamination events can permanently tarnish brand names and business. Also, in some cases food safety standards may be a means to achieve competitive advantage over other firms.
- Many food safety standards used by private firms entail measures that go beyond those required in the LGMA.
- Growers who do not follow these additional food safety measures, sometimes referred to as 'super-metrics,' may have crops rejected or may lose contracts for future business.

## Appendix B: Additional Details on Project Scope and Methods

Overview of Main Qualitative Methods

- *Review of relevant documents, including:* published scholarly literature, farm water quality plans, food safety requirement checklists, unpublished scientific reports, transcripts of testimony, internal memoranda, letters, court rulings, government databases, and policy documents such as laws, regulations, and guidance.
- *Personal interviews with regional experts.* Experts included NGO representatives (agricultural and environmental), government officials (federal, state, and local agencies); industry representatives (growers, handlers, buyers, shippers, auditors, and an attorney), and both scientists and extension agents from the state university system. Time limitations and the project focus precluded us from interviewing retailers and consumers. A Technical Advisory Committee consisting of 36 individuals with expertise in a wide range of research, industry and conservation fields provided extensive input into the research and writing process. Experts submitted more than 2,000 written comments on multiple drafts of the report, participated in three half-day face to face meetings to vet the report, and worked with the research team on an individual basis to provide information, contacts, and other resources. A seven-person team of University of California food safety scientists also provided detailed review and input.
- *Direct observations.* This included field visits to farms, with landowners' approval, to observe management practices and get a stronger sense of challenges. It also included visits to processing facilities.

Overview of Quantitative Methods

- Methodological details of the 2007 survey of 181 growers appears in Beretti and Stuart (2008). RCD (2009) describes methodological details from the 2009 survey of 154 growers.
- Every mail survey has flaws, including the two used for this analysis. Despite shortcomings, the survey methodologies were sound overall given the purposes of the surveys.

Assessing the Quality of Sources

- Considerable scientific uncertainty, opinion, emotion, and politics surround this topic. Thus, this report attempts to gauge the quality of the underlying science regarding specific issues, particularly the amount of evidence available and degree of consensus among experts on its interpretation.
- Additional weight has been given to scientific studies that had been replicated and were conducted in field conditions rather than in a laboratory setting. Priority was also given to peer reviewed scholarly literature and expert opinions from multiple sources with a wide variety of affiliations.

Regarding "Burden of Proof" and Scientific Uncertainty

- As is the case with any policies informed by science, "burden of proof" plays a critical role in current co-management discussions. To what extent should those who create or demand specific food safety practices be required to "prove" that the practices significantly reduce risk? Likewise, must they prove that their practices do not cause environmental damage? Finally, to what extent should those who are concerned about environmental impacts be required to "prove" that significant environmental impacts have occurred?

- We note that parties to the discussion tend to answer these two questions differently, applying a higher standard to others' claims than to their own. This illustrates the role of differential interpretation and values regarding management for food safety and environmental quality
- A certain degree of scientific uncertainty always exists concerning complex, real-world issues, especially those involving natural resources. This tends to steer people toward the well-established precautionary principle, which entails erring on the side of caution when faced with scientific uncertainty.
- Given the persistent lack of 100% certainty, policy makers and others must make difficult decisions based on societal values and an understanding of the best available science. This report does not discuss values, but it does attempt to review and assess the best available science.

## Appendix C
## Glossary of Terms Used in This Report

*[Source: excerpted from RCD 2009, LGMA 2008, and other sources]*

Animals of significant risk: Animals that have been determined by the Centers for Disease Control to have a higher risk of carrying *E. coli* O157:H7. These animals are cattle, sheep, goats, pigs (domestic and wild), and deer.

Anticoagulant: a type of pesticide that interferes with blood clotting and is commonly used as a rodenticide.

Bare ground buffers: areas of bare soil where either crops or non-crop vegetation have been removed for a given width around a field.

Bioaccumulation: A buildup within an organism of specific compounds due to biological processes. Commonly applied to pesticides and heavy metals.

CDFA Auditor: California Department of Food and Agriculture (CDFA) employs specially certified auditors to conduct LGMA audits. These auditors operate with oversight from CDFA, but are certified and trained by the USDA under the auspices of the National Good Agricultural Practice program practices which incorporate the U.S. FDA's Commodity Specific Guidance Documents. Audits are conducted on a regular and random basis, for which LGMA signatory handlers pay through fees.

Co-management: an approach to conserving soil, water, air, wildlife, and other natural resources while simultaneously minimizing microbiological hazards associated with food production.

Concentrated Animal Feeding Operation (CAFO): A lot or facility where animals have been, are or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility. In addition, there must be more than 1,000 'animal units' (as defined in 40 CFR 122.23) confined at the facility; or more than 300 animal units confined at the facility if either one of the following conditions are met: pollutants are discharged into navigable waters through a man-made ditch, flushing system or other similar man-made device; or pollutants are discharged directly into waters of the United States which originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation.

Conservation practice: Actions taken on the land by a land owner or manager/farmer to protect, enhance or conserve a natural resource such as topsoil, water, native vegetation or wildlife. Practices include the gamut from drip irrigation and nutrient management to habitat development, but only those that are considered to have a potential impact on food safety are referenced in this survey.

Constructed wetland: a man-made shallow water ecosystem designed to simulate a natural wetlands and aimed to reduce the pollution potential of run-off and wastewater form agricultural lands.

Copper sulfate: a chemical compound used primarily as an algaecide in ponds.

Critical Habitat: According to U.S. Federal law, the ecosystems upon which threatened and endangered species depend.

Cumulative effects: also called "cumulative impacts": the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Domestic (or Domesticated) Animals: animals including those raised by humans for food production or kept as pets including cattle, sheep, pigs, goats, dogs, and cats.

*Escherichia coli (E. coli)* O157:H7: an enterohemorrhagic strain of bacterium which when consumed can result in bloody diarrhea, kidney failure, and death.

Growers: Individuals and/or companies that grow agricultural products. This report focuses mostly on growers of leafy greens.

Farm ditch: a ditch dug to convey drainage water

Filter strip: an area of vegetation for removing sediment, pollutants, and organic matter from agricultural run-off. Designed to reduce the flow of runoff through filtration, depostion, infiltration, absorption, and volatilization.

Foodborne illness: illness associated with bacteria, viruses, or other pathogens that can be transmitted to humans through the consumption of food.

Food Safety Professional: a person entrusted with management level responsibility for conducting food safety assessments before food reaches consumers; requires formal training in scientific principles and a solid understanding of the principles of food safety as applied to agricultural production.

Handler: Defined by the Leafy Green Marketing Agreement as any person who handles, processes, ships or distributes leafy green product for market, whether as owner, agent, employee, broker or otherwise. This definition does not include a retailer or grower.

Hedgerow (and Windbreak): a living fence of shrubs or trees in, across, or around a field. Used to delineate field boundaries, protect fields from wind and dust, and provide habitat for beneficial insects and wildlife.

Irrigation reservoir: an engineered water holding structure from which water is drawn for irrigation purposes, often built above the level of the surrounding ground by use of an impermeable liner and earth bunds.

Landguard®: an enzymatic treatment that helps break down organophosphate pesticides

Leafy Greens: The fourteen leafy green products covered by the LGMA include iceberg lettuce, romaine lettuce, green leaf lettuce, red leaf lettuce, butter lettuce, baby leaf lettuce (i.e., immature lettuce or leafy greens), escarole, endive, spring mix, spinach, cabbage (green, red and savoy), kale, arugula and chard.

Leafy Green Marketing Agreement (LGMA): California Leafy Green Products Handler Marketing Agreement issued by the Department of Food and Agriculture of the State of California. All actions of the LGMA and its Advisory Board must be approved by the Secretary of CDFA. See www.caleafygreens.ca.gov for more information.

LGMA 'Metrics', or Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens: Food Safety Best Management Practices for Lettuce and Leafy Greens Guidance document developed by Western Growers working with regulatory agencies, scientists, produce industry representatives, and other interested parties. The document is accepted by the Leafy Green Marketing Agreement Board and applies to all signatory handlers and associated growers under the Leafy Green Marketing Agreement.

Non-crop vegetation: Vegetation not harvested as a crop that is either resident or planted in and adjacent to or near farmed land. This includes cover crop (in-field); field border vegetation such as weedy areas, filter strips or hedgerows; and nearby expanses of open non-cropped land, whether in low-statured (grasses, etc.) or tall (trees and shrubs) vegetation regardless of habitat value.

Non-point source pollution: pollution with diffuse sources as compared to pollution with a specific and known outlet.

PAM (anionic polyacrylamide): a soil conditioner that decreases soil loss by holding fine soil particles together in larger aggregates

Pathogen: a disease causing agent. Important pathogens in foodborne illnesses include bacteria, helminths, protozoans, coccoid parasites and viruses (Harris *et al.*, 2003).

Processors: Companies that contract for product to be grown and/or buy, receive and process leafy green products for "value added" packaged products such as bagged iceberg and romaine lettuce, spinach, spring mix, etc. Many processing companies also ship their product to wholesale distributors and retail and foodservice buyers.

Rangeland: Pasture areas on which cattle or other domestic animals graze.

Retail and foodservice buyers: Grocers, restaurants, hospitals, schools, prisons, hotels, cruise ships, military, airlines and others that purchase fresh and/or value-added leafy green products from wholesale buyers, shippers, processors, and growers for sale to consumers. Some corporate grocers and foodservice companies provide their own trucking/shipping fleet to transport products from wholesale buyers or processors

Riparian: of or relating to the banks of a stream, creek or river.

Sediment basin: a basin or off stream pond constructed to capture sediment as well as handle excess run-off. Aims to reduce run-off and erosion and reduce the transport of potential pollutants including nutrients, agricultural chemicals, and pathogens.

Shippers: Companies that transport fresh and/or value-added leafy green products to wholesale distributors and retail and foodservice buyers.

Synergistic effect: when an injury caused by exposure to two environmental factors together is greater than the sum of exposure to each factor individually. For example, an interaction that has more than additive effects; for example, when the joint toxicity of two compounds is greater than their combined, independent toxicities.

Tailwater: The runoff of irrigation water from the lower end of an irrigated field.

Tailwater recovery system: a facility to collect, store, and transport irrigation tailwater for reuse in farm irrigation systems as well as acting as a sediment and nutrient detention basin. Aimed to aid in water conservation and to protect water quality.

Vegetated treatment systems: areas of permanent vegetation used for agricultural wastewater treatment. Aims to improve water quality by reducing the runoff of potential pollutants including nutrients, organic waste, agricultural chemicals and pathogens.

Vertebrates: animals with backbones.

Water bodies: On-farm and near-farm water bodies include man-made and natural features. Man-made water bodies are those that do not occur naturally in the landscape; they range from drainage and supply ditches to irrigation reservoirs and tailwater basins. Natural water bodies include natural ponds, wetlands, rivers and streams.

Wetland: An area of land typically flooded for part of the year with hydrophytic vegetation.

Wildlife: Non-domestic animals including deer, feral pigs, amphibians, reptiles and birds.

## Appendix C
## Scholarly Article Describing 2007 Grower Survey Results

SOURCE: Beretti, M. and D. Stuart. Food Safety and Environmental Quality Impose Conflicting Demands on Central Coast Growers. *California Agriculture* 62(2):68-73

**ARTICLE SUMMARY**: *Growers of fresh produce on the Central Coast of California currently face conflicting demands regarding measures to protect food safety and those to protect environmental quality. To explore the extent of conflicting pressures and identify the range of possible impacts on the environment, we conducted a survey of Central Coast irrigated-row-crop growers during spring 2007. The results indicate that growers are experiencing a clear conflict, and some are incurring economic hardships because their practices to protect the environment have resulted in the rejection of crops by buyers. In addition, some growers are being encouraged to or are actively removing conservation practices for water quality, and most growers are taking action to discourage or eliminate wildlife from and adjacent to croplands. These actions could affect large areas of land on the Central Coast and, as indicated by growers, they are likely to increase over time.*

RESEARCH ARTICLE

# Food safety and environmental quality impose conflicting demands on Central Coast growers

*by* Melanie Beretti *and* Diana Stuart

***Growers of fresh produce on the Central Coast of California currently face conflicting demands regarding measures to protect food safety and those to protect environmental quality. To explore the extent of conflicting pressures and identify the range of possible impacts on the environment, we conducted a survey of Central Coast irrigated-row-crop growers during spring 2007. The results indicate that growers are experiencing a clear conflict, and some are incurring economic hardships because their practices to protect the environment have resulted in the rejection of crops by buyers. In addition, some growers are being encouraged to or are actively removing conservation practices for water quality, and most growers are taking action to discourage or eliminate wildlife from and adjacent to croplands. These actions could affect large areas of land on the Central Coast and, as indicated by growers, they are likely to increase over time.***

**Growers of leafy greens and vegetables must balance the need to improve water quality and wildlife habitat in and around farms, with concerns about food safety.**

The Central Coast of California supports unique biodiversity and some of the most productive agricultural lands in the United States. The Salinas Valley in Monterey County, often referred to as the "Salad Bowl of America," produces the majority of the nation's lettuce. Since the 1990s, food safety has become increasingly important, especially with respect to outbreaks of *E. coli* O157:H7 associated with leafy greens: lettuce, escarole, endive, spring mix, spinach, cabbage, kale, arugula and chard (see www.caleafygreens.ca.gov).

Simultaneously, growers on the Central Coast face increasing demands to protect the environment and have taken a proactive approach to improve environmental quality. An important aspect of these efforts is the adoption of conservation practices, which aim to improve and protect water quality, prevent soil erosion, reduce the use of agricultural chemicals and protect wildlife. However, some food safety requirements — or field-level interpretations of these requirements — conflict with management practices intended to improve water quality and enhance natural habitat.

In response to grower concerns over contradictory guidelines and requirements for food safety and environmental protection, the Resource Conservation District (RCD) of Monterey County conducted a mail survey of 600 irrigated-row-crop growers throughout the Central Coast. The purpose was to better understand the impacts of conflicting demands on growers, and to provide information to aid attempts to reconcile the goals of food safety and environmental protection.

### Protecting environmental quality

The Central Coast contains some of the greatest biodiversity of any temperate region in the world. At its heart is the Monterey Bay National Marine Sanctuary, the largest marine sanctuary in the United States, and the Elkhorn Slough National Estuarine Research Reserve.

While the Central Coast houses many natural resources, according to the Central Coast Regional Water Quality Control Board (CCRWQCB), it also has some of the most polluted waters in California. The Pajaro River and Elkhorn Slough are listed as impaired for sediment and nutrients under California's 2002 Section 303(d) of the 1972 Clean Water Act. The Salinas River is 303(d)-listed as impaired for sediment, nutrients, pesticides and pathogens. In 2003, the 20-year-old state Agricultural Waiver of Nonpoint Source Discharge ended, meaning that growers are no longer exempt from water qual-

Mule deer/U.S. Department of the Interior

*Left*, a poison bait trap and fence to keep small animals out of fields; *center*, a small mammal/amphibian exclusion fence constructed around a tail-water recovery pond; *right*, mule deer. In the survey, a Central Coast grower could not sell $17,500 worth of crops because a food safety audit found deer tracks near the field.

ity laws. In response, the CCRWQCB adopted a Conditional Waiver Program in 2005, which requires growers to enroll in the program, attend water-quality training sessions, adopt farm water-quality management plans, complete management practice checklists and participate in water quality monitoring (Cal EPA 2007).

An important aspect of these efforts is the adoption of conservation practices, which aim to improve and protect water quality, prevent soil erosion, reduce the use of agricultural chemicals and protect wildlife. Vegetation on and around farmland is a key component, including vegetated field borders, grassed waterways, riparian buffers and constructed wetlands. For the past decade, the Central Coast farming community has been proactively working with resource agencies to develop and implement voluntary conservation practices to improve water quality and reduce water consumption through the adoption and implementation of the Monterey Bay National Marine Sanctuary's Agricultural and Rural Lands Plan (MBNMS 1999). Adoption of these practices has now become a key component for compliance with the CCRWQCB's Conditional Waiver Program.

### Protecting food safety

Since the late 1990s, government agencies, researchers and the produce industry have worked to develop and implement voluntary guidelines, or Good Agricultural Practices, to minimize the risk of food contamination (FDA 1998; Bihn 2004). These practices aim to protect consumer health at all levels of leafy greens production and distribution, and they have become increasingly important in light of recent outbreaks. The September 2006 outbreak of *E. coli* O157:H7 associated with bagged spinach from the Central Coast resulted in the loss of three lives and caused more than 200 illnesses. This outbreak affected consumers in 26 states, drawing national attention (CDC 2006) and acting as a catalyst for rapid change in food safety protection efforts for leafy greens. Despite an intensive investigation, the U.S. Food and Drug Administration (FDA) and the California Department of Health Services (CDHS) have not been able to conclusively determine the specific causes of the spinach outbreak (CDHS/FDA 2007).

In early 2007, with oversight by the California Department of Food and Agriculture (CDFA), produce industry representatives developed the California Leafy Green Products Handler Marketing Agreement (see www.caleafygreens.ca.gov). More than 100 handlers (companies that move fresh produce products from growers to retail and food-service buyers) are signatories. Representing more than 99% of the leafy greens production in California, they are obligated to handle leafy green produce only from growers who adhere to the best management practices detailed in the Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens, known as the "Metrics" (see www.caleafygreens.ca.gov). The Metrics were developed and continue to be updated through a process involving the produce industry, government agencies, natural resource organizations and scientists.

In addition to the Metrics, many companies and retailers who handle or sell leafy greens have developed their own company-specific food safety requirements, which also affect farm management practices. Because growers often sell their crops to multiple buyers, most now must meet at least one if not several different sets of requirements. In addition, field interpretations of the Metrics and company-specific guidelines vary. Depending on the size and type of operation, a grower may conduct self-audits as well as undergo food safety inspections and audits by the CDFA, processors, grower-shippers or third-party auditors representing the companies that purchase their products.

Specific measures stated or implied in the Metrics and company-specific requirements may potentially conflict with efforts to improve and protect water quality and support wildlife habitat. For example, the Metrics identify "animals of significant risk" for contaminating crops and provide remediation guidelines. Measures to deter animals and comply with food safety requirements, such as fencing and bare-ground buffers around fields, can also result in adverse impacts to the environment. This may include the alteration or elimination of wildlife habitat, including the removal of surrounding vegetation. Noncrop vegetation is a key component of conservation practices such as field borders, grassed waterways and riparian buffers. Because vegetation provides water filtration and absorption, and reduces the deposition of sediment and pollutants into waterways, widespread vegetation removal could have significant environmental impacts.

### Mail survey to row-crop growers

The Monterey County RCD conducted a mail survey in spring 2007, which was co-sponsored by the Grower-Shipper Association of Central California, the Central Coast Agriculture Water Quality Coalition and the Monterey County Agricultural Commissioner's office. The survey packet and cover letter were mailed to

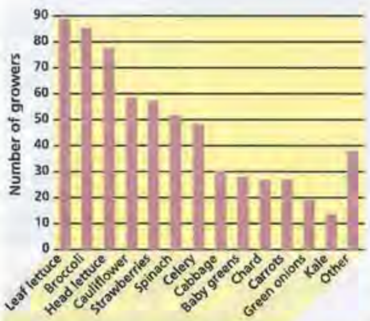



**Fig. 1. Number of respondents who grow each commodity; most grow more than one crop.**

**TABLE 1: Responding growers who have adopted specific conservation practices (n = 181; most growers adopted more than one)**

| Conservation practice | Respondents |
|---|---|
| | % |
| Cover crop | 72.1 |
| Stormwater pond | 38.5 |
| Filter strip | 36.3 |
| Grassed waterway | 33.5 |
| Irrigation reservoir | 30.2 |
| Tailwater recovery pond | 29.6 |
| Hedgerow | 25.7 |
| Riparian restoration | 18.4 |
| Constructed wetland | 6.1 |
| Other | 3.9 |

all 600 row-crop operations listed on the CCRWQCB Conditional Waiver Program's mailing list. These growers had operations in Monterey, San Benito, Santa Barbara, Santa Clara, Santa Cruz and/or San Luis Obispo counties. Three weeks following the initial mailing, a reminder postcard was sent to the entire mailing list.

The four-page survey contained 39 questions, consisting of multiple choice, yes/no, five-point Likert-scale and open-ended questions. Questions included details on farm operations, participation in conservation programs, the adoption of conservation practices, specifics about food safety requirements, information on how respondents are changing or have changed their practices, and opinion-oriented questions to allow respondents to make comments and voice concerns.

The survey also asked respondents about the circumstances under which they have had crops rejected by buyers and auditors due to food safety concerns as well as the economic impacts of these rejections. Growers were asked a series of questions related to food safety, and practices to protect water quality and the environment. The survey sought responses on three main categories of practices and/or natural features: (1) noncrop vegetation, (2) ponds or waterways and (3) wildlife.

Analysis of the results included descriptive statistics as well as the comparison of data between different groups of respondents. We looked at differences between respondents who indicated that they grow leafy greens and those who grow other crops. In addition, we explored how other characteristics such as operation size and type (conventional or organic) affect management decisions. We used the Pearson Chi Square statistic to test for significance.

### Food safety vs. water quality

A total of 181 growers returned surveys, for a 30% response rate. Almost all respondents indicated that they grow more than one crop, primarily leaf lettuce, broccoli, head lettuce, cauliflower, strawberries, spinach, celery, cabbage and baby greens (fig. 1). Approximately 86% grow conventional only or both conventional and organic, whereas 13% were organic only.

More than 80% of the respondents met education requirements of the Conditional Waiver Program through attendance at the Farm Water Quality Planning Short Course and had completed Farm Water Quality Plans. Ninety-one percent (91.1%) had adopted one or more conservation practices aimed to improve water quality and/or wildlife habitat. Sixty-three percent (62.8%) had received technical assistance for water quality or habitat improvement projects from a local resource agency or expert such as the RCD or USDA Natural Resources Conservation Service. Cover cropping was the most common practice adopted by respondents (72.1%) (table 1).

**TABLE 2: Survey responses (n = 181) regarding experiences with food safety audits, concerning the presence of noncrop vegetation, ponds/waterbodies and wildlife**

| Question | Affirmative responses |
|---|---|
| | % |
| "It has been suggested that I should remove *noncrop vegetation*" | 18.6 |
| "I have lost points on audit reports because of *noncrop vegetation*" | 9.6 |
| "It has been suggested that I should remove *ponds or waterbodies*" | 9.5 |
| "I have lost points on audit reports because of *ponds or waterbodies*" | 10.8 |
| "It has been suggested that I should remove *wildlife*" | 39.0 |
| "I have lost points on audit reports because of *wildlife*" | 13.0 |

**Crop rejection.** Eight percent (8.0%) of growers reported that their crops had been rejected based on the presence of practices to improve water quality or wildlife habitat on the farm. Some of the explanations shared by respondents included:

- Lost $17,500 worth of crop due to deer tracks.
- 1 acre of romaine lettuce rejected due to proximity to horse pen.
- 23 acres of head lettuce and 2 acres of mixed lettuce rejected due to contact with Salinas River floodwater.
- Crop rejected due to potential frog habitat.
- Portions of fields rejected by processor if frogs, tadpoles, snails, mice or other small animals were found.
- Harvest stopped due to the presence of frogs and tadpoles in creek.
- Crop rejected due to deer intrusion.
- Crops planted for processor near trees needed a buffer of 100 to 150 feet.

In some cases crops were not rejected outright; however, growers responded that their buyers, auditors or others had suggested either discouraging or eliminating noncrop vegetation, water bodies and wildlife in and around fields. Growers reported they had lost points on food safety audits due to the presence of noncrop vegetation (9.6% of respondents), water bodies (10.8%) and wildlife (13%) near their crops (table 2). Growers also indicated that in some cases they acted in response to buyer/auditor suggestions and actively removed these features or adopted mitigation measures accepted by their auditors or buyers. In all three categories (noncrop vegetation, water bodies and wildlife), growers of leafy greens were more likely to have been told to discourage or eliminate these features than growers of other crops. In two of the three categories (noncrop vegetation and wildlife) leafy greens growers were

TABLE 3: Comparison of affirmative responses by leafy green versus nonleafy green growers (n = 181) to questions concerning the removal of conservation practices or natural features in or adjacent to cropland

| Question | Growers of Leafy greens | Growers of Nonleafy greens |
|---|---|---|
| | % | % |
| "It has been suggested that I should remove *noncrop vegetation*" | 32.1* | 2.8 |
| "I have actively removed *noncrop vegetation* in response to comments by auditors or others" | 32.1* | 6.9 |
| "It has been suggested that I should remove *ponds or water bodies*" | 14.8* | 3.0 |
| "I have actively removed *ponds or water bodies* in response to comments by auditors or others" | 7.4 | 6.0 |
| "It has been suggested that I should remove *wildlife*" | 47.7† | 27.9 |
| "I have actively removed *wildlife* in response to comments by auditors or others" | 40.7* | 23.5 |

* $P < 0.05$.
† $P < 0.10$.

significantly ($P < 0.05$) more likely than growers of other crops to have acted on these suggestions (table 3).

**Conservation practice abandonment.** Approximately 15% of all growers surveyed indicated that they had removed or discontinued the use of previously adopted conservation practices in response to suggestions made by auditors or buyers due to food safety concerns. Growers of leafy greens were significantly ($P < 0.05$) more likely to have taken out conservation practices than other growers: 21.1% indicated that they had actively taken out one or more conservation practices due to food safety concerns, as compared to 7.4% that grow nonleafy green crops.

Practices that had been removed or were planned for removal included: (1) ponds and/or reservoirs (such as irrigation reservoirs, duck habitat and ponds); (2) irrigation reuse systems (such as tail-water recovery ponds and water reuse); and (3) noncrop vegetation (such as grassed waterways, filter/buffer strips and trees/shrubs). In addition, some growers stated that although they had not yet removed conservation practices, they were planning to or felt they would be required to in the near future. Several respondents suggested that a follow-up survey would reveal more changes being made.

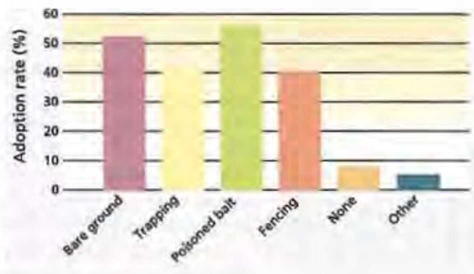



**Fig. 2. Percentage of respondents who indicated they have adopted specific mitigation measures for wildlife.**

**Wildlife exclusion.** Some 88.9% of the survey respondents indicated that they had adopted at least one measure to actively discourage or eliminate wildlife from cropped areas (fig. 2). The most commonly adopted measures were: bare-ground buffers, fencing, trapping and poisoned bait stations. Bare-ground buffers and poisoned bait stations were each used by more than half of the respondents to protect crops from wildlife intrusion. Trapping and fencing were each used by approximately 40%. Growers of leafy greens were significantly more likely to be using bare-ground buffers ($P < 0.05$), poisoned bait stations ($P < 0.05$) and traps ($P < 0.01$).

**Growers most affected.** Results from the survey suggest that the conflict between food safety and environmental protection disproportionately affects respondents who sell to shippers and packers, operate on more than 500 acres and grow conventionally (as opposed to organic only). Of respondents who had removed conservation practices, 87.8% sell to shippers and packers, whereas only 67% of all respondents sold to shippers and packers. Of respondents who had removed conservation practices 89% operate more than 500 harvested acres, whereas only 39% of all respondents operated more than 500 harvested acres.

In addition, large farm operators (> 500 acres) were significantly ($P < 0.05$) more likely to have been told to eliminate wildlife and waterways and significantly more likely to have adopted mitigation measures. Of the respondents who had removed conservation practices, 100% grew conventionally (conventional, and conventional and organic operations), whereas 86% of all respondents grew conventionally.

**Acreage affected.** The growers who responded to the survey manage more than 140,000 acres of row-crop land on the Central Coast. Of these, those who had actively removed conservation practices for water quality or wildlife habitat (in response to suggestions by food safety auditors or others) manage nearly 30,000 acres. In addition, respondents who had adopted measures to actively deter or eliminate wildlife manage more than 133,000 acres. Survey respondents that use bare-ground buffers manage 91,890 acres (65% of the total land reported); trapping manage 87,279 acres (62%); poisoned bait stations manage 108,283 acres (77%); and fencing manage 66,380 acres (47%).

**Grower comments.** More than 30% of all respondents also chose to share their personal opinions and concerns at the end of the survey. These comments indicated that many growers face serious pressure regarding food safety, and they are concerned about doing things that may have negative impacts on the environment. Their responses suggested that in many cases growers have little choice in their management practices and must be responsive to buyers' and auditors' suggestions in order to sell their crops. For example, one grower wrote: "I am afraid many positive environmental programs and practices are going to be abandoned due to retailers'/shippers' new food safety practices. I am all for the environment and safe food, but feel many new food safety ideas are being driven by fear and uncertainty rather than sound science."

And another wrote: "Our experience has been that the food safety auditors have been very strict about any vegetation that might provide habitat. We are very concerned about upsetting the natural balance, but we have to comply with our shipper's requests."

### Conflict on the Central Coast

The survey results illustrate that growers are in the middle of a clear conflict between current food safety standards and continued efforts to address water quality and environmental concerns on the Central Coast. It appears that growers of leafy greens who operate larger acreages are especially affected by food safety concerns; however, other growers are also affected to a lesser extent. Growers are incurring economic hardships due to the rejection of crops based on the presence of practices to protect the environment. Some growers are encouraged to or are actively removing conservation practices in response to food safety audits and concerns. Many growers are taking action to discourage or eliminate wildlife and other noncrop vegetation. These actions could have impacts over large areas of land in the region. In addition, comments from growers indicated that these actions are likely to increase over time as food safety standards become more established. The survey also indicated that growers are concerned about being put in the unfair position of choosing between being able to sell their crops or protecting the environment.

Protecting human health and insuring the viability and sustainability of California agriculture demands safe food, clean water and biodiversity. However, the virulence of *E. coli* O157:H7 coupled with the consumption of raw leafy greens poses an unprecedented challenge to the produce industry. Our survey results indicate that current practices to address food safety in the field may result in environmental concessions including habitat loss, degradation and continued water-quality impairment. The removal of noncrop vegetation, for example, can include common conservation practices such as filter or buffer strips, grassed waterways, riparian habitat, natural lands, hedgerows and windbreaks. Discouraging or actively removing these features will have negative environmental impacts and, in some cases, could actually *increase* the risk of crop contamination (Stuart 2006; Stuart et al. 2006).

For example, contamination in overland water flows may be reduced by filtration through perennial forage or grasses (Tate et al. 2006). Vegetated treatment systems (such as grassed waterways and vegetated basins) have also been shown to reduce the presence and transport of pathogens (Kadlec and Knight 1996; Koelsch et al. 2006). Lastly, constructed wetlands have been found to effectively remove pathogens in water through filtration in dense vegetation, sedimentation, microbial competition and predation, high temperatures, and UV disinfection (Hench et al. 2003; Nokes et al. 2003; Greenway et al. 2005). Given the results of these studies, further evaluation of food safety standards requiring the removal of vegetation may be necessary.

**Growers are concerned about being put in the unfair position of choosing between being able sell their crops or protecting the environment.**

Scientific uncertainty plays a significant role in the current conflict, particularly regarding animal sources of *E. coli* O157:H7. Although studies agree that cattle (Hancock et al. 1998; Chapman et al. 1997) and some commensal wildlife species (associated with humans) are known sources of *E. coli* O157:H7 (Fenlon 1981; Meerburg et al. 2004), most studies on pastoral wildlife (associated with natural environments) do not illustrate a substantial threat to food safety. Studies looking at pastoral small mammals and deer showed minimal prevalence of *E. coli* O157:H7 (Hancock et al. 1998; Sargeant et al. 1999; Fischer et al. 2001). Studies also indicate that there is a very low probability (0–1%) that birds associated with natural environments will carry pathogenic bacteria that could contaminate food crops (Brittingham et al. 1988; Hancock et al. 1998). More recently, *E. coli* O157:H7 was isolated in feral swine near spinach fields and cattle on the Central Coast following the 2006 spinach outbreak (Jay et al. 2007). Deer and geese residing in high densities in watersheds heavily populated by humans and dairies have been identified as sources of *E. coli* O157:H7 in New York state (Somarelli et al. 2007). Despite these studies, there is still much uncertainty regarding the role of wildlife specific to the Central Coast region.

New scientific studies are already under way to investigate the role of wildlife and vegetation in food safety, as well as other sources and vectors of *E. coli* O157:H7 on the Central Coast. Although new studies will improve our understanding of risks to food safety, they will not be able to provide 100% certainty or eliminate all possible sources of contamination. Therefore, it becomes essential to weigh relative risks and focus attention and resources on the most likely sources of contamination. How current and future standards affect the risk of contamination should be evaluated. For example, conservation practices that have been shown to reduce the presence and transport of human pathogens could be an asset in meeting food safety goals. Keeping produce as safe as possible is a critical goal; however, the means to achieve this goal should be carefully investigated to insure those measures actually reduce risks of crop contamination, do not increase other human health risks as a result of environmental degradation, and are cost-effective and practical to implement.

This survey was conducted during the spring of the first growing season following the development and adoption of the California Leafy Green Products Handler Marketing Agreement. Because food safety pressures have continued to intensify — with a proliferation of food safety guidelines and increased field audits — our results likely present a conservative estimate of the on-the-ground impacts of this conflict. As standards and measures are developed to protect food safety, government and industry leaders should be conscious of how these measures affect growers as well as the environment.

The process and standards for protecting food safety in leafy greens on the Central Coast of California set a precedent that will certainly be modeled for other crops and growing regions nationwide. As of January 2008, efforts were being put forth to develop a Federal Marketing Agreement and provide the foundation for a Federal Marketing Order for leafy greens. In addition, private industry and companies that buy fresh produce continue to develop mandatory field-level food safety requirements that go beyond the currently adopted Metrics.

Based on the survey results — and ongoing efforts of the agricultural community and local, state and national organizations — there is a clear need to alleviate conflicting pressures facing growers. Resolving this conflict will require an open dialogue between scientists, environmental and food safety organizations, and leaders in the produce industry to create management standards that support both food safety and environmental stewardship. We have the opportunity and responsibility to learn from this conflict on the Central Coast, and insure that our agricultural and natural resources are successfully co-managed for human and environmental health.

*M. Beretti is Program Director, Resource Conservation District of Monterey County, Salinas; and D. Stuart is Doctoral Candidate, Department of Environmental Studies, UC Santa Cruz.*

*Thanks to our co-sponsors: the Monterey County Agricultural Commissioner's Office, Grower-Shipper Association of Central California and Central Coast Agricultural Water Quality Coalition. Additional thanks to: Rene Aguas, Jo Ann Baumgartner, Jim Bogart, Jennifer Clark, Sam Earnshaw, April England, Jeane Errea, Margaret FitzSimmons, Chris Goodson, Lea Haratani, Dina Iden, Robert LaFleur, Eric Lauritzen, Jessica Lee, Bob Martin, Dawn Mathes, Laura G. Mills, Deborah Nares, Joe Pezzini, Carol Presley, Daniel Press, Bob Roach, Traci Roberts, Rami Shihadeh, Kathy Thomasberg, the USDA Natural Resource Conservation Service and the Region 3 Water Quality Control Board.*

*This study was funded in part by the Community Foundation for Monterey County (#20040679), the California State Water Resources Control Board (#04-326-553-0 and 05-122-553-1) and USDA Natural Resources Conservation Service (#65-9104-7-611).*

**Border strips around fields, shown on a Central Coast farm, help improve water quality by filtering runoff into and off of farmland. However, such strips may also create habitat for small animals, which may be perceived as a food safety risk.**

### References

Bihn EA. 2004. Food Safety Begins on the Farm: Reduce Microbial Contamination with Good Agricultural Practices. Cornell University, Department of Horticulture. 2 p. www.gaps.cornell.edu/Educationalmaterials/Samples/PamphletEng.pdf.

Brittingham MC, Temple SA, Duncan RM. 1988. A survey of the prevalence of selected bacteria in wild birds. J Wildlife Dis 24(2):299–307.

[Cal EPA] California Environmental Protection Agency. 2007. Water Quality: Irrigated Agricultural Waivers Program. State Water Resources Control Board. www.waterboards.ca.gov/agwaivers (accessed Feb. 15, 2008).

[CDC] Centers for Disease Control and Prevention. 2006. Multistate outbreak of *E. coli* O157 infections, November-December 2006. www.cdc.gov/ecoli/2006/december/121406.htm (accessed June 15, 2007).

[CDHS/FDA] California Department of Health Services and US Food and Drug Administration. 2007. Investigation of an *Escherichia coli* O157:H7 Outbreak Associated with Dole Pre-Packaged Spinach. Sacramento CA. www.DHS.ca.gov.

Chapman PA, Siddons CA, Malo ATC, Harkin MA. 1997. A 1-year study of *Escherichia coli* O157 in cattle, sheep, pigs and poultry. Epidemiol Infect 119(2):245–50.

[FDA] US Food and Drug Administration. 1998. Guidance for Industry: Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables. Center for Food Safety and Applied Nutrition. Washington, DC. www.cfsan.fda.gov/~dms/prodguid.html.

Fenlon DR. 1981. Seagulls (*Larus* spp) as vectors of Salmonellae: An investigation into the range of serotypes and numbers of Salmonellae in gull feces. J Hygiene 86(2):195–202.

Fischer JR, Zhao T, Doyle MP, et al. 2001. Experimental and field studies of *Escherichia coli* O157:H7 in white-tailed deer. Appl Env Microbiol 67(3):1218–24.

Greenway M. 2005. The role of constructed wetlands in secondary effluent treatment and water reuse in subtropical and Australia. Ecol Engin 25(5):501–9.

Hancock DD, Besser TE, Rice DH, et al. 1998. Multiple sources of *Escherichia coli* O157 in feedlots and dairy farms in the northwestern USA. Prevent Vet Med 35(1):11–9.

Hench KR, Bissonnette GK, Sexstone AJ, et al. 2003. Fate of physical, chemical, and microbial contaminants in domestic wastewater following treatment by small constructed wetlands. Water Res 37(4):921–7.

Jay MT, Cooley M, Carychao D, et al. 2007. *Escherichia coli* O157:H7 in feral swine near spinach fields and cattle, central coast. Emerg Infectious Dis 13(12):1908–11.

Kadlec RH, Knight RL. 1996. *Treatment Wetlands.* Boston: Lewis. 893 p.

Koelsch RK, Lorimor JC, Mankin KR. 2006. Vegetative treatment systems for management of open lot runoff: Review of literature. Appl Eng Agric 22(1):141–53.

[MBNMS] Monterey Bay National Marine Sanctuary. 1999. Water Quality Protection Program. Action Plan IV: Agriculture and Rural Lands. Monterey, CA. http://montereybay.noaa.gov/resourcepro/reports/agactioniv_99/ag99_about.html.

Meerburg BG, Bonde M, Brom FWA, et al. 2004. Towards sustainable management of rodents in organic animal husbandry. Njas-Wageningen J Life Sci 52(2):195–205.

Nokes RL, Gerba CP, Karpisak MM. 2003. Microbial water quality improvement by small scale on-site subsurface wetland treatment. J Env Sci Health Part A-Toxic/Hazardous Substances and Env Eng 38(9):1849–55.

Sargeant JM, Hafer DJ, Gillespie JR, et al. 1999. Prevalence of *Escherichia coli* O157:H7 in white-tailed deer sharing rangeland with cattle. J Am Vet Med Assoc 215(6):792–4.

Somarelli JA, Makarewicz JC, Sia R, Simon R. 2007. Wildlife identified as major source of *Escherichia coli* in agriculturally dominated watershed by BOX A1R-derived genetic fingerprints. J Env Manage 82:60–5.

Stuart DL. 2006. Reconciling Food Safety and Environmental Protection: A Literature Review (1st Ed.). Resource Conservation District of Monterey County. Salinas, CA. www.rcdmonterey.org.

Stuart D, Shennan C, Brown M. 2006. Food Safety versus Environmental Protection on the Central California Coast: Exploring the Science Behind the Apparent Conflict. UC Santa Cruz, Center for Agroecology and Sustainable Food Systems. Res Brf #10. http://casfs.ucsc.edu/publications/briefs/index.html.

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

## Appendix E: Executive Summary from the 2009 Grower Survey

NOTE: for a full copy of the report, please email the RCD of Monterey Country at: paul.robbins@rcdmonterey.org

### I. EXECUTIVE SUMMARY

Growers on the Central Coast of California face increasing demands and liability to both protect environmental resources and ensure a safe food supply. Consumer concerns are heightened, national legislative efforts to develop mandatory, enforceable food safety standards are underway, and growers are under increasing pressure to comply with a complex array of food safety requirements and environmental regulatory obligations. The coordinated management (**co-management**) of food safety and environmental protection is being challenged by conflicts arising between these priorities, placing the agriculture industry in the difficult position of having to develop reasonable food safety standards and risk reducing actions based on an insufficient body of science to guide those efforts. Successful **co-management** must be informed about both the drivers and on-the-ground impacts resulting from the challenges confronting the agricultural industry.

The Resource Conservation District of Monterey County, in collaboration with conservation organizations and agricultural industry groups, conducted a mail survey of Central Coast irrigated row crop operations to obtain a clearer understanding of the drivers and impacts of this conflict. This survey was developed to:

- *Better understand the key drivers presenting obstacles to* ***co-management*** *within the production, marketing, distribution and retail chain;*
- *Determine which farming operations are experiencing the most pressure as a result of the conflicting demands; and*
- *Assess if and how the on-the-ground impacts of these challenges have changed over time.*

In the spring of 2009, the survey plus two follow-up post cards were mailed to all 647 known irrigated row crop operations on the Central Coast (San Mateo, Santa Cruz, Santa Clara, San Benito, Monterey, San Luis Obispo and Santa Barbara Counties). We received 178 completed surveys (27.5% response rate).

Leafy green growers, large operations and conventional operations were most likely to experience co-management challenges. In addition, some organic operations and operations that produce strawberries, Brussels sprouts, and artichokes were facing similar challenges. The survey also found that respondents who sell their produce to **processors** or national or international buyers were most likely to experience challenges to co-management. Respondents who sell to grower-shippers reported similar experiences, but the survey suggests that some of the competing requirements coming through grower-shippers were originating from buyers higher up the market chain (processors and national/international buyers). In the current climate of zero tolerance for risk, co-management efforts are facing significant obstacles. The survey data suggest that the use of the Leafy Greens Marketing Agreement "Metrics" and food safety programs employed by national or international buyers and processors were most likely to present obstacles.

The survey also suggests that food safety professionals conducting in-field audits were having a strong influence on co-management efforts. Respondents encountered potential obstacles to co-management as a result of in-field risk assessments that identify food safety concerns associated with environmental features and the requirement that corrective action is taken as a conditional requirement to be able to sell the produce grown in proximity to the features of concern. Respondents who sell to processors and national or international buyers experienced more pressure from the auditors representing these companies that may result in challenges to co-management. Respondents were in a challenging position needing to balance steps to ensure safe food with environmental protection goals.

The sometimes seemingly incompatible demands between food safety and environmental protection and subsequent actions taken to address food safety concerns associated with environmental features have the potential to result in negative environmental impacts. The data suggest there was a reduction in the use of the less environmentally sensitive practices since 2008. As the agricultural community refines its approach to protecting food safety, the in-field dynamic between food safety and environmental protection will continue to evolve.

Respondents were investing significant resources into efforts to ensure food safety and protect the environment. Growers also were bearing the majority of costs and losses as a result of conflicts between food safety guidelines and environmental protection. Economies of scale appeared to be a relevant factor placing smaller operations at a disadvantage and potentially increasing their financial susceptibility to costs associated with increasing regulations and challenges to co-management.

The results of this survey contribute significantly to our understanding of some of the drivers and points of influence creating challenges to co-management for food safety and environmental protection. Based on these findings, it is clear that efforts to promote co-management will require open dialogue and collaboration amongst the agricultural industry (including handlers and buyers), food safety scientists and private companies, human health and environmental regulatory agencies, and environmental scientists and organizations.

# Appendix F. Summaries of Grower Interviews from March-April 2009

*NOTE: The following notes have been redacted to protect the anonymity of the growers interviewed. Individual buyer and auditor company names have been removed and noted generically as BUYER or PRIVATE AUDIT COMPANY. Names of specific landscape features are redacted. Acreage is described in four groups: 200-500 acres, 500-1000 acres, 1000-3000 acres and > 3000 acres. The term "grower" has been used to refer to the interviewee throughout, though some interviewees may be managers of food safety or other aspects of farm management. Interviewees were selected from several counties in the Central Coast region.*

## Grower 1

*(> 3000 acres, assorted vegetables and lettuce, mostly conventional).*

Approximately 97% of their operation is conventional and 3% organic. They grow a variety of vegetable crops as well as lettuce, including romaine, and cabbage for FIVE BUYERS

On Food Safety Standards

The LGMA standards seem reasonable and doable to grower. There have been some costs associated with the LGMA due to the required fee and increased paperwork and water testing. However, most of the food safety measures they already had in place due to demands from their buyers. The BUYER standards, on the other hand, are "so extreme they are barely manageable." Now OTHER BUYERS are copying BUYER and starting to use similarly extreme standards because they have to compete. Grower says, "They are playing catch-up." "They are so far on the side of caution, just to minimize liability." BUYER has strict rules about amphibians. They refused to take crops from a whole ranch that is about 1800 feet long because there was a pond with tadpoles in it on one end of the ranch. Normally, this grower would have just added copper sulfate to the pond, but the pond was right by their organic fields so they didn't want to. So they could not sell anything from that ranch to BUYER. Grower says, "It was ridiculous."

Grower applies the LGMA standards to all ranches and all vegetable fields. This is because the areas where certain crops are grown change frequently. Overall, food safety has been expensive requiring four full-time employees for paperwork and audits and two people to check bait stations regularly. Food safety management has cost them about $38 an acre. Grower does not think that food safety pressure is still escalating, but rather that standards are more stringently enforced now. Grower tells a story of how, last year, an auditor representing a buyer said they would take crops a half-mile from domesticated animals (even though their standards require a one mile buffer), but this year on the same property they said they would not take the crops. They claimed that now they "could more accurately measure the distance." Grower added, "it is not like they invented new ways of measuring distance anytime recently." His experience has been that food safety measures from these companies are not negotiable. Grower has made some changes even before being told to do so because grower knew that there would be problems otherwise. One time, five acres of cropland were rejected due to animal intrusion and they lost about $17,000 in one shot.

The LGMA audits seem fine and they get good marks. Grower would not say they are terribly consistent, though. Some auditors are "more picky than others." Auditors from processors and buyers are not consistent at all and it can depend on the market. The auditors "change their minds depending on the market." For example, grower describes how once some pigs ran through his field of lettuces. When BUYER came to harvest half of it they marked off about 40 feet on all sides of the pig tracks and harvested the rest. They came back for the rest of the field the next week, but in the meantime a hurricane had hit Mexico and wiped out the crop down there. They were short on produce and cut within two feet of the same pig tracks, totally violating both their own and the LGMA standards. Grower is frustrated by these events and says, "and they say it is not market-related!" Grower describes another incident that happened to someone grower knows. BUYER came to harvest and flagged off a corner of the field where there were animal tracks and harvested the rest. Then later, for a field at the same location, they rejected 20 acres of crops because of the same tracks, just because the market had changed and was flooded (they did not need the produce). Grower explains why the growers are powerless in these situations, "there is a short list of people you can grow for and some of them own the land you farm." The larger impacts to farmers and the farming community include more stress and costs, and some growers say they have had enough and retire early. "It is causing more soul-searching." Grower thinks that new food safety standards might make food safer because everybody is doing something about it now. The most important thing is to bring the baseline up a bit. Now everyone is more conscious about things.

On the Environment

Grower has made buffers and rearranged crops to meet buffer requirements. They did not have conservation practices, but were planning to, and buffer requirements made them decide not to. They have stopped using ponds for irrigation, but have not filled them in. They have not put in fences, but have about 2000 bait stations and thousands of mousetraps. They would have to install three to four miles of fence, so fencing is not economical. They have taken out a bunch of grasses and weedy vegetation and removed trees to reduce foreign object contamination complaints. Grower explains that BUYER is "paranoid about frogs." As described above, they refused crops from an entire ranch due to tadpole presence. Therefore, they treat almost all of their ponds with copper sulfate to avoid such scenarios. "It is expensive to use copper sulfate, but they put it in all ponds and ditches." Grower states that copper sulfate is intended to reduce bacteria as well as to eliminate amphibians. Grower is not sure about the environmental impacts of copper sulfate. Grower thinks, "it probably breaks down pretty quickly and is probably not an issue."

BUYER'S auditors told grower to remove vegetation from along a creek because it could harbor wildlife. Grower refused because "the area is already erosion prone and it would be a disaster." They still take crops from those fields, so it must be ok for now. Grower says, "there is no question that these standards are impacting the environment." Grower says that the LGMA standards aren't as bad as the private company standards. They are trapping all of the mice, and sometimes birds get in the traps. Grower is not sure how all this impacts the food chain and the foxes and coyotes. His perception of wildlife has changed. Before, grower thought that animals were nice to see, and now they only portend a big problem. They are currently paying their neighbors to not have horses and goats on their land just so they don't have to have big buffers. Grower says food safety standards (both LGMA and private standards) put them in a hard place regarding practices for water quality and erosion control. Grower explains, "the processors say you can't plant grass without a big buffer, but to have the big buffer you have to take so much land out of production that it would cost so much money. It is not possible."

Not being able to use their tailwater, they have to dump more water downstream now. Grower explains they can't even use it for dust control. Grower shares, "the water quality farm plan has not dictated anything. Although it is a thought-provoking exercise, it doesn't really influence our practices." However, grower recalls how after hearing about pesticide levels in [*name redacted for anonymity*] creek they decided to keep their tailwater out of the creek and actually set aside two acres of land in order to sprinkle back the tailwater onto the land rather than put it into the creek. Grower states, "and this is land that could be being used to grow crops and costs us $1200/acre in rent."

## Grower 2

*(grower and grower-shipper, >3000 acres, leafy greens, vegetables, conventional)*

Grows iceburg lettuce, romaine lettuce, red and green leaf lettuce, celery, chard, kale and a variety of vegetables. They function as a grower and also a grower-shipper. They sell to THREE BUYERS.

On Food Safety Standards

Grower thinks that pressure regarding food safety seems to be leveling off now. Grower does not think that new food safety standards are putting any growers out of business. They apply the LGMA standards to everything they grow, even broccoli and cauliflower. "It is easier to treat all of the fields the same." They have to use even stricter standards for their buyers. The CDFA audits have not really affected them. They have found a few things that were minor. The CDFA auditors are not all that consistent. "The newer auditors seem to be a bit overzealous." Grower thinks that the water sampling measures are "overboard."

Food safety standards are expensive because of the costs for personnel and the paperwork. "There are so many audits." The LGMA has added costs through water testing requirements. They have only lost a little bit of land due to buffers. TWO BUYERS have extreme requirements. "Their buffers are too big." They also have a "huge fear of amphibians... they see any tadpoles and they say to get rid of them." They have lost up to $17,500 at one time due to animal intrusion. Although grower has heard of it happening, s/he has not experienced any auditors changing their standards based on the market.

On the Environment

Grower has removed vegetation and trees in response to auditors' comments to keep fields clean. The auditors representing the buyers were making demands prior to the LGMA. They would give grower a list of prohibited blocks of land from which they would not take product with an explanation of why it was prohibited. For example, the document would say, "too close to trees," "too much vegetation nearby" or "near ponds and reservoirs." BUYER, to whom they sell heads of lettuce, is the strictest. Ponds are a big problem. "We used to have ponds with fish and tulle that were nice to see, and now we have to clean them out." They use copper sulfate on two ponds they have and filled in another reservoir by bulldozing it over. "It was too much of a pain to manage." Grower reports that they have not put up any fences, but have gotten depredation permits from Fish and Game for pigs. They also have lots of bait stations in their fields.

Grower thinks that the LGMA rules do conflict with water quality efforts. They farm on pretty flat land and have never installed any conservation practices, but have removed other vegetation and trees. They removed willow trees and eucalyptus. Grower knows of one farm located on steep slopes that had to get rid of its conservation practices due to food safety issues with their auditors. Grower thinks that BUYER standards really conflict with environmental efforts.

Grower's perception of wildlife has changed a bit, "maybe." Grower likes having wildlife around and seeing wildlife, "but not in my fields." In his/her fields, wildlife has become a problem. They have cannons and noisemakers in order to keep wildlife away.

### Grower 3

*(grower-shipper, 1000-2000 acres, leafy greens and vegetables, all organic)*

Grower # 3 runs a large organic vegetable business that grows over 40 different vegetables. Grower is a grower-shipper and sells to FIVE BUYERS.

On Food Safety Standards

The buyers requested they use PRIVATE AUDIT COMPANY to have audits a couple times every year. Now they also have the CDFA auditors for the LGMA. They had to sign the LGMA when Canada said it would not take any produce that was not certified by the LGMA. The standards that the buyers require do not exceed those of the LGMA, but it is starting to sound as if they might in the future. BUYER really wants them to use Global GAP standards. The CDFA auditors seem pretty consistent so far. They have turned down pre-harvest requests from their buyers.

The LGMA requires more paperwork and that fields look cleaner. Fences have been costly, and the overall load on the operation has increased because of monitoring and inspections. Grower says, "small farmers can't survive if they are having to implement all of this stuff. They can't afford to take the costs and spread it through the operation. I haven't heard of anyone going out of business, but they can't comply with certain standards."

On the Environment

For the LGMA standards, they have had to take out vegetation to make 30 foot buffers around fields and have had to clear out brush to put up fences. The fences are designed to keep deer out. They also use noise at night, like talk radio, but it doesn't seem to work. They created setbacks from all waterways. They had and continue to have conservation practices. They put in hedgerows and have been able to keep those. They just tell the auditors that it is essential to have beneficial insects, even though the auditors don't like it. They had to take their buffer strips out. Grower says, "if you don't follow the LGMA rules, you lose your crop and can't sell it. If you take out the conservation practices, you lose nothing."

Grower does not think that the standards are based on science. "There is no science to back them up. They say remove vegetation, but I have seen studies showing that filter strips have just the opposite effect [reducing chances of contamination]." Grower goes on to explain, "Well they don't actually say remove it, but they say you must have a buffer around it if you want to keep it or you can't plant around it. So we have to take out the strips. That is business." The CDFA auditors do tell them they can't harvest fields with too many animal tracks in them. So they have to keep wildlife away.

Grower says that the LGMA standards have definitely impacted the environment and conflict with environmental efforts. Grower says that fencing off the land cuts off wildlife movement and that taking out filter strips will increase erosion and runoff. "The LGMA definitely contradicts with water quality, but food safety puts you out of business faster, so you have to follow those rules." Grower's view of wildlife has not really changed because s/he has always tried to keep them out of the fields. Grower says, "my attitude about wildlife hasn't changed, but our management has changed because it has been forced on us. Deer and wildlife don't carry E. coli, cattle and people do."

### Grower 4:

*(grower, 500-1000 acres, lettuce and artichokes, conventional)*

Grower # 4 grows artichokes and bulkhead lettuce – all conventionally grown. Grower does not do any shipping.

On Food Safety Standards:

The only standards impacting grower are the LGMA standards. Grower does not sell to any buyers who require additional standards. BUYER has its own auditor, but grower also complies with the LGMA standards for now. Grower has applied the LGMA standards to all of his fields (leafy greens or not), but has less pressure to follow standards with the artichokes. Grower believes that pressure regarding food safety is still increasing, since grower is being asked to do more things all the time. Grower believes that the LGMA auditors are fairly consistent with their remarks. Grower has not experienced BUYER switching its standards or any rejections based on market conditions, but grower has heard of it happening. Adopting the LGMA has required some adjustments, but has not been too bad. Grower thinks that a few measures, such as monthly water tests, are a bit overboard. Putting up fences has been the most costly piece in addition to the loss of cropland through the creation of buffers. Grower thinks that food safety measures are especially hard for small growers who have less staff and resources. Grower believes that food safety standards as required by the LGMA are probably making food safer overall.

On Environmental Impacts:

Grower has taken out vegetation, "all kinds and any kinds," in a 40 foot buffer zone around fields. Grower has also installed deer fences around fields. The auditor did not tell grower to install the fence, but grower installed it due to problems with animal intrusion and fear of crop rejection. One time grower lost $50,000 due to raccoon and deer tracks in a field. Grower does not use bait stations. Grower has never installed any conservation practices for water quality beyond using cover crops in the winter. Grower has no waterways or ponds on the land grower farms. Grower believes that the LGMA standards definitely conflict with efforts to reduce erosion and protect water quality. Grower sprays all vegetation to keep the fields clean and says that doing so will increase erosion and run-off. Grower is sure that there is more erosion from the fields now. "You can see all the new sources of erosion just from driving around." Grower does not believe that his/her perceptions of wildlife have changed and still likes wildlife. "I put up all the fences because I don't want to shoot the deer."

### Grower 5

*(1000-2000 acres, growers, lettuces and vegetables, conventional and organic)*

They are growers and do not do any shipping. They produce a variety of vegetables and lettuces. They sell to FIVE BUYERS.

On Food Safety Standards:

They try to apply the LGMA standards to all of their crops. Grower thinks that, overall, food safety pressure is leveling off a bit, or at least it is less hectic than before because everyone is getting used to it and accepting it as part of the process of farming. The CDFA auditors come a couple times each year. They also have audits from TWO PRIVATE AUDIT COMPANIES and auditors from the shippers. CDFA takes notes on conditions and does not make any suggestions or give advice. They note proximity to standing water and other things and follow the rules of the metrics. Grower says that animal harborage has not been a problem for CDFA auditors. Other auditors from shippers and third party certifiers give instructions on what should be done to mitigate problems. They have told them to put in bait stations and remove vegetation. They have been asked to remove vegetation around wells. Grower says that the LGMA is not a problem and is actually improving as the metrics are refined. Grower says, "the real problem is the arms race between shippers, who are probably getting pressure from retailers." Grower describes how, in many cases, one shipper with new requirements forces you to retool the whole operation because it is easier to standardize everything. They had to hire a new person to deal with food safety, and that was costly. The shippers' requirements are "too much" and require larger buffers that are difficult to make. Grower says, "One auditor for BUYER said they would not take crops within two miles of a compost pile, even though the same compost goes on the fields." Grower thinks that small farmers are not going to be able to meet all of the demands because they won't have enough time to produce all of the documentation that is required. "If it isn't written down, it is like it didn't happen."

The LGMA auditors seem consistent with their comments (they do not reject fields, only send reports to the main office), but the shippers' auditors do not seem consistent. They had a contract with BUYER for processed lettuce on two fields. The first field was ready to harvest but was rejected due to animal intrusion (deer tracks). The second field was not mature yet, but it too was rejected it too because it was in close proximity to the deer tracks. At this time, the market was "in the dumps." They disked the first field but left the second one, hoping to find another buyer. When the market picked up, however, BUYER called back and wanted the second field it had previously rejected. Another time when the market was bad, BUYER rejected a field that had bird poop on it. They said it had rained too much that they could not see where the poop was and flag it off. However, other times when they could not identify where birds had pooped, BUYER still took the crops.

On the Environment:

They have worked with the RCD to install conservation practices. They have a total of seven locations with grassed waterways and/or catch basins. Grower says, "the auditors [for BUYER] said these were possible harborage for wildlife and wanted us to either get rid of them or put buffers around them." They called up the boss at BUYER and told grower what the auditor said and that they would not install a buffer or fence or remove the waterways and catch basins. BUYER still bought the crops. Grower says, "any standing water is a concern and needs to be crystal clear." They use chlorine and copper sulfate, which grower says is pretty expensive. They treat the ponds now before the auditors even say anything because they know if it is murky and not clear, it will be a big issue. They try to get rid of most standing water by pumping it out. They can't use reservoirs anymore and filled a couple in. They have also filled in ditches, but not grassed waterways. Their biggest and oldest grassed waterway is now "a huge liability," and they are considering removing it. "It has a history as an audit topic and they have to argue about it every time." Grower says it is also a lot of work to keep out unwanted vegetation and keep it mowed and clean. They have hired a night watchman who drives around all night making noise to scare away wildlife. They have not put up any fences, but do have depredation permits. They have bait stations with poisoned bait and traps according to different auditors' requests. Last year, they placed the bait and traps everywhere as a preventative measure and as "eye candy for the auditors." This year, they are only putting them up when requested. They do a lot of things "preemptively" because they know that auditors will be unhappy with things. Their "preemptive" measures include bait stations, grass and brush removal, tree trimming and the application of copper sulfate to ponds.

He thinks that food safety standards from shippers and processors are impacting the environment. "More pesticides are being used for vegetation and rodents. We would not be putting copper sulfate in the ponds if we didn't have to. We have to because if we don't we would definitely lose the contracts and lose our business." There is more erosion now. "We had a hillside with annual grasses and shrubs and knew it would be a problem, so we disked it, and now we have 'rill' erosion down the hillside that is filling up our ditches." There are also impacts on wildlife. They did not want to put up fences, so they got depredation permits to appease the auditors. They have to use the permits a bit or else they might be taken away, but they don't want to kill the deer. Grower is not sure if the LGMA makes it harder to protect or improve water quality, but grower says that the shippers' requirements definitely conflict with water quality goals. Regarding water quality, grower says, "we are not quite back to the way it was 15 years ago, but we are definitely going backwards, with more pollution coming from the ranches."

Grower says that his/her perception of wildlife has definitely changed, "I hate to say it, because I am more of a nature lover than most of them. I liked wildlife being around, but now I view it as more of a pest than before. Other people used to shoot a coyote, when I thought about how it was eating squirrels and other pests. Now I see a coyote and think how much money it could cost me." Grower says that food safety requirements and water quality efforts put them in a difficult position. "Many practices for water quality directly conflict with the 'scorched earth' requirements for food safety, but food safety wins because it affects if we stay in business." Grower says that water quality is important too, but can't compete. Grower says that if they want to stand up to their buyers' standards it could make them look like a "black sheep." "It is hard to fight against food safety. It is like fighting against world peace. But all the stuff we have to do is not for food safety. It is just an excuse to do other things, and the concept is being used by the buyers."

### Grower 6

*(grower/shipper, 500-1000 acres, lettuces and vegetables, conventional and organic)*

Grows lettuce, romaine, broccoli, Chinese cabbage, endive, escarole, radicchio, and frisée. They mostly function as a grower but do a little bit of shipping as well. They are about 90% conventional and 10% organic. They sell to FOUR BUYERS

On Food Safety Standards:

Grower says they apply the LGMA to all crops because it is easier to have one set of standards. CDFA conducts audits for the LGMA. The auditors have a checklist that they have to stick to. There are no surprises because it is all based on the metrics. They seem to be very consistent and do a good job. They don't give any suggestions or advice. They would simply write that there was too much vegetation in proximity on the report. They will look for wildlife intrusion and if they find it, they do not do anything and might not even note this in their report. If something is wrong, the LGMA people will send them back the report and give them a time frame in which to address the problem, but they don't tell them how to fix it. The CDFA auditors don't look for amphibians. They stick to their checklist. If they try to deviate, this grower tells them it is not on the checklist, and they drop the issue. Grower says the LGMA rules are "reasonable and seem to be working." Grower says, "the LGMA is no problem, it is like an open book test. You know the rules and it is crystal clear."

Grower says the shippers have more strict standards than the LGMA. They call for bigger buffers from waterways and animals. They have some room for negotiation regarding water-testing schedules. Grower thinks that pressure regarding food safety seems to be leveling off a bit. Grower thinks that the LGMA is getting "well refined" and that most of the buyers are using the LGMA (except for processors). Grower explains how TWO BUYERS' standards go above and beyond the LGMA with bigger buffer zones, rules about amphibian presence ("they are paranoid about amphibians") and thorough inspections of waterways. Grower thinks that BUYER is now coming around and getting their standards closer to those in the LGMA, except as far as buffer zones are concerned. All of this has been costly, but mostly in terms of personal time, as grower spends about half a day each week on food safety. Overall, it is probably not forcing anyone out of business, but it is time consuming.

Grower says that auditors for the shippers "absolutely" are inconsistent and change their minds. Grower describes one experience grower had where BUYER said it would not take any crop from a ranch due to "the potential for amphibians." So they made a deal with someone else to harvest it. But after the other company came and said it was clean, BUYER changed its mind, bought it from the other company and harvested it. Grower says, "When the market is good, they will take it. Their own standards are flexible, and if it is clean they will take it." Grower says, "On the other side, if the market is bad, they will find an excuse not to take it. BUYER rejects whole fields. Food safety is used as a tool not to accept some crops due to market conditions."

On the Environment

They have fenced around their organic ranches whose crops they sell to BUYER. It is the only place they have any wildlife presence. They also have a depredation permit for wild pigs. Processors want to see clean ponds and no amphibians, so they use copper sulfate. Grower's catch basins present a problem and must be treated for amphibians. On most of his ranches, they do not have much wildlife. Although they have wildlife near their organic ranches, they tell the food safety auditors that it is part of the organic standards and they can't try to control wildlife. The auditors then go back to using the LGMA standards for their organic fields and flag off areas where there has been animal intrusion. On the conventional fields, the buyers request that bait stations be put up. They are no longer allowed to use their reservoirs because they could attract wildlife. Without being told to do so, in general they keep all of the ranches cleaner because they know auditors will be looking at them. If frogs are present, they will be prohibited from growing for processors in certain blocks, not matter how much copper sulfate they use.

Grower thinks the processors' standards impact the environment. Grower says, "I am not happy about using copper sulfate. I would rather coexist with the frogs." On some of the ranches with really bad amphibian problems grower has let the leases go. Grower says, "You can't control Mother Nature- when frogs want to cross your field, they are going to cross your field." Grower also thinks that, in general, cleaner ranches will have more runoff. Grower explains that his organic fields are near some steep slopes that they keep planted with vegetation through the winter. Grower says that if this were a conventional farm, there is no way they could keep that vegetation, and its removal would result in a lot of erosion. Regarding organic operation, grower says, "we don't want it to be sterile- we want the good insects around." They have grassed waterways and catch basins near the organic fields, but none near the conventional. When the auditors complain grower just tells them, "Sorry, it is part of the system." However, they suggest grower removes them almost every day, and it is a constant problem. However, Grower says, "If we didn't catch the tailwater, it would just flood over into other fields." Some buyers won't take crops from this field, but grower has found other buyers with "less stringent standards."

Grower is not sure if the LGMA conflicts with efforts to improve water quality. Grower explains that his fields were all already pretty clean before the LGMA. The other standards have greater impacts. Grower says that his perception of wildlife has changed. "Wildlife use to be free to roam as long as there was no crop damage. Now all the organic ranches are fenced off because wildlife means you lose money." Grower says that growers do put poison out for birds and that has been going on for years, partly to reduce what the birds eat when crops are germinating.

## Grower 7

*(Grower/shipper, 1000-3000 acres, vegetables, lettuce, spring mix, organic and conventional)*

Grower for a big shipper . They grow almost all vegetable crops and lettuces, including spring mix. About 25% of their production is organic. They sell to grocery store chains and also to processors including THREE BUYERS.

On Food Safety Standards:

They try to apply the LGMA to all crops, because that is what their customers want. Grower says, "the LGMA audit is just an audit. They don't do any advising and they are fairly consistent. Some of it depends on if the auditor is having a good or bad day. But it is black and white and you know what to expect." Grower says the CDFA auditors are not looking to reject your fields. If they find any wildlife intrusion or tracks, they simply want to see how you handle it, "Do you flag it off right, are you documenting everything." Grower says that they don't tell you how to fix any problems; they just write it up on the report and do not consult. While the LGMA is alright, grower says that the "real problem is not everybody is on the same page and want other requirements. These companies are all trying to be one step ahead and it needs to all be the same." Grower says that other auditors representing different processors and customers are totally different. They come in and say, "You need to do this and do that." Grower says that the salad plants are the worst and those that buy heads of lettuce are not too worried. Grower says that their demands are not negotiable.

Grower reports that processors are definitely inconsistent with their standards. "If they need a crop bad, they will take it. For example, just yesterday they changed the date on an old audit and used it because there was not time to do a new one that the customer wanted." Grower says that in other cases, "they will look the other way." Grower explains that once the processor banned a ranch, but then when they really needed product, they bought from that ranch anyway.

On the Environment:

Salad plant auditors tell grower, "This tree is too close, you are too close to the river, too close to cows." Grower says that they say, "If you remove this, then I will approve it." They have been told to increase buffers, cut down trees and remove brush. Grower says that, due to BUYER, they cut down about 3000 Eucalyptus trees. BUYER told grower that the trees provided too much habitat and had to go in order for them to buy product. They have also removed big oaks and cypress trees. They are required to use bait stations, so they do. They have fenced along the river to keep out deer and pigs. They use blue tablets of copper sulfate in all of their ponds. Grower says that the processors "don't like frogs." They treat all standing water for all crops. Most ponds need to hold tailwater, but if they are unnecessary, they just fill the reservoir. They are not allowed to use the reservoirs anymore so they just bulldoze them over.

He says that they use cover crops to reduce erosion in the winter where there are steep slopes. They don't have any grassed waterways. Grower thinks that all of the demands for fences and for keeping birds out are overkill. The environmental impacts include "impacts to squirrels, field mice, and birds –and the fencing cuts off pathways." Grower thinks that food safety conflicts with water quality goals in some places where you are not allowed to line the banks with vegetation due to possible wildlife habitat. Grower says that the food safety issues have definitely impacted his view of wildlife. "I used to see a fox and thought it was cool. Now I see a fox and it pisses me off, and I want to shoot it and bury it with a backhoe. This is all because of food safety."

### Grower 8

*(grower, 500-1000 acres, lettuce and vegetables, conventional and organic)*

They grow asparagus, alfalfa and romaine, green leaf, red leaf and head lettuce. They are just growers and do not do any shipping. They sell to THREE BUYERS. They have about one tenth of their land in organic or transition to organic production.

On Food Safety Standards:

They apply the LGMA to all crops except alfalfa. The CDFA auditors come a couple times each year. Their auditors have mostly consistent except for one instance, when an auditor was looking into his shed and examining equipment not even used for leafy greens. It seems to grower like the auditors are getting better. The first year, the auditors were not as consistent, and now they stick to their check-list. The CDFA auditors have never brought up any issues regarding wildlife and wildlife habitat. Grower says that BUYER have standards that are pretty much in line with the LGMA. BUYER is much more stringent regarding their water testing and the proximity of crops to creeks and ditches. Grower explains that they used to grow crops for processing, for TWO BUYERS, but their standards were so severe that they got out of the processing business and now only grow commodity crops. That changed everything. Grower thinks that food safety demands are leveling off. "We are learning more and backing off of certain areas." Grower says that companies and buyers are still ramping up and "want them to be more and more sterile." Grower thinks that lawsuits are driving this.

Grower personally has not recently experienced any inconsistency with the buyers. Grower does not sell to processors anymore, however. Grower says they used to have problems when they sold to BUYER. "We were in a processing deal with BUYER and got out because their excuses were due to the market, not food safety. In a good market, they would trip over themselves for garbage crops."

On the Environment

They have never had a whole field lost to intrusion and do not have any depredation permits. BUYER wants bait stations up, and they did this the first year and put up stations all over. But now they only put them up if there is a problem. They installed a barrier fence last year. They have not had to remove much vegetation. They were told to remove some shrubs and trees but refused to. BUYER still took the crop. Grower explains that they are in a good position because they have great ground and are really good growers. Therefore, they can negotiate with buyers and find other buyers if one is being too strict. For them, grower says that food safety does not conflict with water quality. Grower says that because they are a top grower they have more power. They have had grassed waterways in for 15 years and the auditors are used to it. If the new auditor has a problem, grower calls up the boss, and if they don't want their product, they find another buyer. Grower says they are in a pretty good situation. Grower says his perspective of wildlife has changed a bit over the years. Overall, though, grower likes wildlife and says, "Farming will never be sterile, so don't try to make it that way- there is not that much you can do."

### Grower 9:

*(grower, 1000-2000 acres, lettuce and vegetables, conventional)*

Currently grows lettuces, artichokes, cauliflower, broccoli and celery. They sell their artichokes to BUYER and the other crops to FOUR BUYERS.

On Food Safety Standards

They apply the LGMA standards to every crop. All of their shippers require the LGMA standards for all vegetable crops, even those not eaten raw. They have only had one CDFA audit so far. The auditor stuck to the checklist and did not do any advising. Grower cannot say if the CDFA auditors are consistent because they have only had one audit. All of the shippers go beyond the LGMA in their own way. They are stricter regarding flooding and the widths of buffers. One of the shippers, BUYER, now requires that Global GAP standards be met. Food safety pressures are still ramping up and have not leveled off yet. The shippers are definitely inconsistent with food safety standards. Grower says that although farm has not personally experienced this inconsistency, knows that it exists. The LGMA paperwork and documentation is really burdensome. Regarding shippers and buyers' standards, grower says, "Everyone is trying to one-up each other, especially in retail. They all want to claim to have the safest food."

On the Environment

They have ranches right along the [*name redacted for anonymity*] river. This is a problem regarding animal intrusion, because the shippers won't take their crops where there is animal intrusion. They lost 10 acres of crop, about $32,000 worth, from one incidence of deer intrusion. They have had to build fences all along the river, and more will be added. There is a fence between their fields and a wildlife refuge as well. They have been asked to remove riparian vegetation along the river, but they told the auditors (representing a shipper) that "it is protected riparian vegetation and we cannot remove it." The shipper still took the crops. Other auditors representing shippers have asked them to remove trees, and they comply when the landlord will allow it. They have depredation permits for deer, but fences are more effective. The fences are very expensive, though. "It cost us $100,000 to fence off a 180 acre ranch." Bait stations are used in the winter, and traps are used during harvest season for rodents. They cannot have amphibians and use frog fences where needed. They cannot have any standing water. They don't use copper sulfate, because they don't have any more standing water.

Grower says that food safety is definitely negatively impacting the environment. The fencing impacts wildlife migration. They have to have everything clean and all the ditches clean, which means "less grasses and less filtration." Grower says there is probably more runoff now. Grower says that all of their perceptions of wildlife have changed. "It used to be cool to see deer and a fawn out in field. They didn't eat that much crop- but now they are public enemy number 1. Whole fields and ranches can be rejected due to deer." Grower says they need to prove that deer don't carry *E. coli* O157:H7. "They need to take deer off the list; they don't carry it." Grower says that the deer standard is overkill. Grower also says that there is a lot of conflict between the Ag waiver program and the LGMA and shippers' standards.

### Grower 10:

*(grower, >3000 acres, lettuce and vegetables, conventional and organic)*

They grow head lettuce, leaf lettuce, romaine, celery, broccoli, cauliflower, carrots, onions, pumpkins and strawberries. They sell FIVE BUYERS.

On Food Safety Standards

They apply the LGMA to all of their crops and even try to apply them to strawberries. They have had a total of 14 CDFA audits for the LGMA. They have not all been consistent, especially early on. Some of the auditors were "more diligent than others." They are now getting better at sticking to the list, but they can all interpret the list differently. Grower says, "wildlife and vegetation are not an issue with the CDFA, because all of the shippers have much higher standards that we were already following." The CDFA auditors do not give suggestions or advice; they just ask questions and take notes.

The shippers' auditors do give suggestions or tell them what they need to do in order for them to be able to buy their crops. They say, "You can't grow for us in this field," or "You need bigger buffers around this field." All of them have standards beyond the LGMA with bigger buffers and more water sampling. They will either flat-out reject the crops or tell them to change something in order for them to be able to buy the crops. Grower doesn't think any of this is really making food any safer. They didn't find anything in their tests before and do not find anything now either.

The shippers are definitely inconsistent regarding what makes crops acceptable or not. Once they knew a shipper who had too much romaine at the moment. The shipper rejected a whole ranch's worth of romaine for vague food safety reasons. But someone else took the crops right away- there was no problem with them. Grower says, "The market drives the standards. If the market is really good, it is amazing what they will turn their heads to."

On the Environment

They are asked to clear brush and put up fences along the [*name redacted for anonymity*] river. They were not directly asked to put up fences, but they had crops rejected due to deer intrusion. Seeds from cottonwood trees would get into the romaine, so they had to cut down a bunch of the trees. They have removed a lot of grass and shrubs because the auditors like to see clean fields. They have also removed a lot of saplings. Most all of their ponds and reservoirs have been bulldozed over because they were a problem. Frogs have not been a big issue for them, since they don't have water bodies around anymore. Their catch basins were mostly all bulldozed. They have bait stations everywhere. They don't use traps, only bait or nothing. Grower says, "They have been really good at eradicating the squirrels." On their strawberry fields they have bird traps. They also use bird blasters – noisemakers – and shoot blanks in order to scare away the birds. They do have depredation permits for deer. They have lost up to $250,000 in one incident from deer intrusion. They also have pig traps. They do have one old catch basin that used to have reeds in it. They had to put copper sulfate in it.

Grower says that there are definitely environmental impacts resulting from the food safety standards, both the

LGMA and the shippers' standards. They have had to fence whole ranches and are "clearing habitat and poisoning ponds." Grower says that there is more run-off due to less vegetation. Their CCOF auditor suggested they plant some vegetation around their organic ranch that is hillier and prone to erosion. Grower responded, "Yeah right. That is not possible with food safety rules." They used to have grassed waterways, but had to kill all of the vegetation due to food safety standards. Grower says that people are putting out bird poison illegally.

Grower says the LGMA definitely conflicts with the Ag Waiver program. All of their water is going into the river, and they cannot use catch basins and vegetation, so more water is going into the river. Grower says, "People can't do these practices anymore because they are not allowed to have grasses." With the LGMA, although they are technically allowed to have grasses, "the buffer requirements for the LGMA make it unreasonable to install conservation practices." Grower says that you have to have a buffer of at least ten feet on each side and that "ten feet along a mile and a half is a lot of land that could be farmed." Grower says if you need the buffer on both sides that is at least 20 feet out of production on each side. That is not practical for business. Some people are using hay roles to reduce erosion instead of grasses. The standards from their shippers really conflict with the Ag waiver program. They are telling them to remove habitat and vegetation and have even larger buffer widths from potential habitat. BUYER's standard is 50 feet from potential habitat. Grower says that their perceptions of wildlife are changing a bit. While they never really wanted to see wildlife in their fields before, "now they are more aggressive to keep it out at all costs."

### Grower 11

*(Grower, 500-1000 acres, lettuce and vegetables, conventional)*

Grow iceberg lettuce, broccoli and radicchio, green beans, broccoli and cauliflower for seed and organic romaine and broccoli. They sell their produce TWO BUYERS.

On Food Safety Standards

They apply the LGMA metrics to all of their crops because the shippers demand it. They have only had one CDFA audit and so cannot say if CDFA audits are consistent. The audit went fine, and the auditor stuck to the checklist. Grower did give a bit of advice and took a little "artistic license" during the audit, but they did not have any problems. All of the shippers have their own pre-harvest audits. Grower says, "When all this first started, we had neighbors with horses and could not use 200 acres due to the new buffer requirements. Now we have to use that land for growing seeds. We grew on that land for years with no problems. It is perfectly good land." They have had parts of fields rejected due to dog tracks and lost over $1000. Grower thinks that the water testing required by the LGMA is a bit overboard. The shippers say they have to have these standards for consumer confidence and that they "have to do it for the customer." But grower thinks, "It is not making food any safer- if it has, it is insignificant." Grower thinks the real problem is the mechanical harvesting of greens. "It is done at night in the dark and people can't see what they are harvesting." Overall, grower says food safety pressures seem to be leveling out a bit.

They have not experienced their shippers being inconsistent with food safety standards, but grower has friends that have. Grower says BUYER does it to growers all the time. Grower explains that when the market is really good, BUYER will buy crops from people that don't even following their year-round food safety program. That makes everyone who does follow the program really mad. One other grower that grower knows told BUYER that grower would sue them if they were to do that again.

On the Environment

Grower is told to keep wildlife out by his shippers, but says, "I don't know if you really can keep wildlife out." The shippers tell grower to keep all of the field borders clean and to "make the environment inhospitable to wildlife." Grower says, "Wildlife are just trying to exist- so we just make it so there is nowhere to hide, drink or eat around here." They used to have grasses in the ditches to reduce erosion, but now they keep the ditches sprayed and clean to keep wildlife out. Grower admits that now they have more erosion. They put copper sulfate in their ponds because the shippers say they must have a pond policy. Grower states that copper sulfate is used for water quality, to allow more light in to kill bacteria. Grower says they don't really have frogs around here.

Grower says that there are considerable environmental impacts. "Everything we do is an environmental impact." Grower says they are making things "cleaner" on the fields, which is causing more erosion and run-off. They used to have grassed areas and grassed waterways "that were beautiful" and now they have a "scorched earth policy." They got some free engineering from the RCD or the NCRS and had a tailwater system installed. It was really efficient, with up to 90% efficiency. Grower says, "Now it is worthless, because we are not allowed to use it. Now we have to waste a bunch of water."

Grower says that both the LGMA and the shippers' requirements conflict with water quality practices and the Ag Waiver. Grower says, "They are exactly opposite. If you plant grasses to reduce non-point source pollution (which is important), it flies right in the face of food safety standards." Grower explains, "The buffer zones make it unreasonable to have grassed areas." They can't afford to take 50 feet out of production for the buffer zones, so they keep the ditches clean. Grower says that grower has always liked seeing wildlife because grower is a hunter and an outdoorsman. Grower doesn't personally feel any different about them, but his "responses are different." Grower doesn't get angry at squirrels, but in contrast to prior years, s/he now responds by putting out more bait stations.

## Grower 12

*(grower, 200-500 acres, lettuce and herbs, conventional)*

Grows red lettuce, green lettuce, head lettuce, endive, and butter lettuce, all conventionally. grower sells to THREE BUYERS.

On Food Safety Standards

They have PRIVATE AUDIT COMPANY come out on behalf of several shippers, so they apply the PRIVATE AUDIT COMPANY standards to everything they grow. Grower says the PRIVATE AUDIT COMPANY standards "encompass the LGMA standards." The CDFA auditor has only come once so far, so grower cannot say if CDFA auditors are consistent. The auditor used the checklist and did not deviate from it too much. They did not do any advising. The other auditors are different. Grower has auditors from TWO PRIVATE AUDIT COMPANIES and TWO BUYERS. All of these auditors do advising, grower says. They want everything to be sterile, "but nothing is a guarantee, they just want something to hang their hat on." Grower is frustrated and says that "microbiologists working for these big companies are making the rules, but they have no idea about farming and the realities of the farm environment." Grower thinks that food safety pressures are still increasing and are not leveling off yet. What grower finds "most disturbing" is how retailers pressure the shippers into having these standards and the growers have to pay for it all. Grower thinks that food prices should go up to incorporate the increased costs of food safety.

He says that shippers are definitely inconsistent and change their standards due to changes in the market. Grower explains that if a shipper is short on lettuce, or if they can get a good price for it "they have a tiny buffer around a gopher hole." Grower says that when the market is bad, or if they have too much product "they flag off huge areas or reject entire fields for no reason." Grower says that the shippers are really ruthless. Grower describes what grower calls "harvesting blight" – when crops are rejected at harvest for no apparent reason. Food safety is used as an excuse in many cases.

On the Environment

He has been told by his shippers to put out bait stations. They used to have about 100 and now they have around 1000. They also installed a three-foot high fence along the creek to keep out rodents. They were told to remove vegetation along the creek that could serve as habitat and harbor wildlife. They cleared out a huge section of the creek. "We probably took out about 90 truck loads of brush from along the creek." TWO PRIVATE AUDIT COMPANIES told them to remove it. They don't have any depredation permits for deer. They have a few reservoirs that they were treating with copper sulfate but have switched to ozone because it is less expensive, grower thinks. The auditors are really concerned about frogs, but they don't have any on his farm to speak of.

Grower says that the LGMA does conflict with the Ag Waiver and water quality programs. They don't have any conservation practices, but grower explains, "We would like to." Grower says, "Grassed waterways and food safety don't mix." Grassed waterways would be habitat for rodents and amphibians. "Shippers and buyers want a sterile condition and this conflicts with practices for water quality and wildlife."

He thinks there are definitely environmental impacts from new food safety standards. "We are cleaning out trees and brush- making it sterile. The grasses removed increase run-off. We have hillsides with no grasses now and I have to push the soil back up the hill. We used to have grasses, but they said it harbored wildlife." Grower says that his perception of wildlife has changed. When grower sees a deer now, grower really wants it to keep off of the property because there are serious financial consequences – whole fields can be rejected.

## Appendix [illegible]:
## Fresh Express Standards Information

### PART 1: Response to Request for Information Regarding On-farm Food Safety Management Standards

Quote below provided by Mike Burness, Vice President, Global Quality and Food Safety, Chiquita Brands International/Fresh Express, July 27, 2009

*"The Fresh Express buffer zone is several hundred feet from grazing cattle. In regard to other wildlife, the goal is to minimize potential animal intrusion to prevent possible pathogenic contamination. Fresh Express consistently works with its growers, one-on-one, to identify possible contamination risks, and requests them to develop relevant solutions. These solutions may vary based on time of year/season, crop, exact location of the field, surrounding flora/fauna, proximity to water sources, and so on. Fresh Express takes a customized rather than one-size-fits-all approach.*

*With respect to flooded ground, Fresh Express inspects the ground prior to planting to ensure appropriate mitigation at that early stage, with flooding being one of the criteria that is assessed. Here too there are variables that would be taken into consideration in determining a length of time before re-planting. Generally, a few months would be considered sufficient.*

*With respect to overall environmental sustainability, our goal is to take a proactive stance regarding Ag practices that are designed to mitigate potential pathogenic contamination within the context of a sincere respect for the land, wildlife and eco-system. Fresh Express values food safety and believes that food safety and environmental conservation are not competing values. They are both vitally important. To that end, Fresh Express works closely with regulatory agencies on conservation efforts. As an example, it is currently working with USDA researchers on agricultural conservation and in California works with the California Department of Fish and Game."*

## PART 2: Fresh Express Food Safety Standards, Cited in *USA Today* Article and Downloaded from Company Website

EXCERPTED FROM: Schmit, J. 2006. 'Fresh Express Leads the Pack' in Produce Safety. *USA Today*, October 23, 2006. online 10/01/09 at http://www.usatoday.com/money/industries/food/2006-10-22-fresh-express-usat_x.htm

**Here's the production chain, and some of Fresh Express' safety measures:**

### 1 Growing

Fresh Express gets most of its product from California's Salinas Valley. Fields and operations are inspected three times each crop cycle.

**Growing times** (in summer, weeks)

Lettuce: 10½

Spinach: 4½

**Nearly ready:** Executive Vice President Jim Lugg inspects heads of iceberg lettuce for harvest in Salinas, Calif.

By Jack Gruber, USA TODAY

#### Fields

**Fresh Express won't accept produce from fields if:**

- They're within one mile of a cattle feed lot or dairy operation. Cattle operations may cause E. coli to get into runoff water and onto a field, especially during floods.
- They've been flooded within five years.
- They're within several hundred feet of a cattle pasture.
- They're within 150 yards of rivers, or habitat that attracts wildlife that may spread contaminants.
- They catch water runoff from cattle pastures.

#### Water

**In Salinas, Calif., well water irrigates fields and is drawn from aquifers 800 to 1,000 feet below ground.**

- Water is tested monthly for pathogens during the growing and harvesting season. Before the recent E. coli outbreak, water was tested at least three times a year.

#### Animals

Because animals can spread E. coli, tracks in a field make that part of the field unfit for harvest. Often, 30% to 40% is affected. Two years ago, Fresh Express stopped buying lettuce from Florida because growers couldn't keep frogs out of the crop, which then had to be destroyed. To protect fields:

- Rodent traps, checked daily, are set about 50 feet apart along the field's edge. Carbide cannons, which sound like shotguns, are set off by timers to scare off birds.
- Fences may be required to keep out deer, wild pigs, cattle and other animals. Evidence of wild pigs makes land unharvestable for two years.
- Workers' dogs are not allowed in fields or in trucks.

#### Fertilizing

Fresh Express prefers growers use cover crops to add organic matter. Crops such as wheat and barley are planted but plowed under before harvest.

- Raw animal manure is banned because it may contain E. coli.
- Composted animal manure is being phased out because of fear that bacteria may survive fermentation and heating.

## Appendix H:
## Crop Contamination

Overview of processes of crop contamination

- Contamination of fresh produce can occur at any point along the supply chain. The supply chain after harvest varies for different products. After harvest produce may be processed in the field or beyond, sold to retailers or food service outlets or directly to consumers. Some products are cooled and transported, others are sold in local markets. Most fresh produce will be stored for some period of time before consumption. Contamination may occur at any point along the field to fork supply chain.

- Sources of contamination for fresh produce include the following: feces (animal or human):soil, irrigation water; inadequately composted manure; biosolids; air (dust); wild and domestic animals; insects; human handling; interactions between plant foragers including birds and insects (nematodes, slugs, flies); run-off from livestock operations; water used to mix agrochemicals; harvesting equipment; transport containers; wash and rinse water; sorting, packing, cutting and other processing equipment; ice for cooling product; transport vehicles; improper packaging, cross contamination with other foods and water used in hydrocooling. Improper storage, packaging or display temperatures may all lead to bacterial growth and increased risk. Note that this list is intended to display the many potential sources of pathogens and their proliferation, not to imply that they are all important factors in Central Coast fresh produce contamination episodes. List compiled from Harris *et al.* (2003) and Doyle and Erickson (2008).

- Foodborne illness outbreaks result from contamination by several kinds of pathogens, including bacteria, helminths, protozoans, coccoid parasites and viruses (Harris *et al.*, 2003).

- This report focuses specifically on *Salmonella* spp. and *E. coli* O157:H7, which are among the pathogens considered serious public health risks associated with fresh produce (Beuchat 2006, Altekruse *et al.*1997, Tauxe1997, Francis *et al.* 1999). The reason for this focus is the national level of attention on foodborne disease that occurred during the 2006 *E. coli* O157:H7 contamination of fresh produce from the Central Coast region.

- Pathogenic bacteria, such as *E. coli* O157:H7, typically cannot persist for long periods of time in the environment. This is due to the fact that they are adapted to a different environment (e.g., the gut of warm-blooded animals,), where sufficient nutrients are provided and the environmental conditions are well-suited to their survival. In the soil or water environment, it is unlikely that they will encounter conditions that are optimal for their survival and/or reproduction, thus limiting their persistence.

Terminology relevant to pathogen hosts and vectors

- Pathogen vectors include any agent that helps move the pathogen from a reservoir toward a point of contamination. There may be many vectors that move a pathogen through the environment or the supply chain before it is ultimately in contact with food products. Pathogen vectors include animals, humans, insects, water and any other organism or material able to move the pathogen toward a contamination site.

- Reservoir hosts serve as a source of the disease agent to vectors, but usually are not adversely affected. Reservoir animals typically are vertebrates such as mammals and birds.

- Incidental hosts are vertebrate animals infected with a disease-causing agent that are not essential to the development and transmission of the agent. For example, humans can be infected with West Nile Virus (and may suffer severe illness or death), but we are not essential to the development and transmission of the virus. (Hill and MacDonald, 2008 at http://www.entm.purdue.edu/publichealth/glossary.html#v)

Methods of killing pathogens in fresh produce

- Because fresh produce is often consumed without a "kill step" (a step in food preparation that will kill any pathogens not removed by washing) avoidance of contamination is paramount.
- Attempts to kill many important pathogens, including *E. coli* O157:H7, with chlorine wash water are only partially effective (Takeuchi and Frank, 2000).
- New technologies using calcinated calcium, ozone or irradiation are currently under investigation (Fonseca and Ravishankar, 2007). While they may one day be a practical way to reduce pathogen contamination of fresh produce, important questions about consumer acceptance of treated product, effectiveness, cost, effect on produce nutritional quality and practicality of widespread use remain.

Source tracking to help understand processes of contamination

- A number of techniques for characterizing pathogens and help identify sources of contamination have been developed (Cooley *et al.*, 2007; Yan and Sadowsky, 2007; Guan *et al.*, 2002; Gentry *et al.*, 2006). With the development of microbial source tracking techniques, which allow researchers to attempt to match characteristics of pathogens from contaminated produce with characteristics of pathogens from different potential contamination sources at the field level, re-constructing the pathways of contamination has progressed considerably.

## Appendix I
## Supplemental Information about Sources of Pathogens

Rationale for selecting studies for inclusion in wildlife table.

The table was compiled using data collected in a previously published review of the potential role of wildlife in contamination of fresh produce (Stewart and Berretti, 2006). Further input was solicited from advisory committee members, particularly from scientists actively researching the potential role of wildlife in contamination of fresh produce. Database searches were used to find supporting documents when an individual indicated that they thought there was information regarding the prevalence of a given species, but could not provide a reference.

As stated in the report, we primarily focused on *E. coli* O157, with some consideration of *Salmonella* to broaden the report's focus to include a second major pathogen of concern in fresh produce. When *Salmonella* (or other known food-borne illness pathogens, e.g., *Campylobacter*, *Cryptosporidium* spp., *Giardia duodenalis, Shigella, Yersinia*) were also tested in a given study, the results were included. The focus was primarily on prevalence of pathogens in wildlife species, specifically those that the CDC identifies as animals of significant risk — wild pigs and deer. The report notes the risk presented by domestic animals that the CDC includes in its list of animals of significant risk (e.g., cows, sheep, goats), but does not focus on them. When a study that provided data regarding prevalence in a wildlife species also included prevalence in domestic animals, the results were included. Prevalence data in the table is most extensive for cows, as much of the research on pathogen prevalence has focused on them.

A systematic search of the literature was conducted using the Web of Science/All Databases. Key word searches were done for "*Escherichia. coli* O157 wildlife", "*Escherichia. coli* O157 wild pig", and "*Escherichia. coli* O157 deer". Also, the 2009 survey results indicate that growers have been told that rodents, amphibians and birds are a risk to food safety. These terms were searched in the same database with key words "*Escherichia. coli* O157 rodent", "*Escherichia. coli* O157 amphibian", *Escherichia. coli* O157 bird" and "*Escherichia. coli* O157 frog". A total of 176 hits were found. After duplicate references were deleted 130 references remained. An additional search list of 130 references compiled by a UC Davis graduate student was cross referenced to ensure that no relevant material was missed.

Web of Knowledge/ All Databases, last search January 20, 2010:

Wildlife *Escherichia coli* O157 (47 hits)

Deer *Escherichia coli* O157 (57 hits)

Wild Pig *Escherichia coli* O157 (18 hits)

Rodent *Escherichia coli* O157 (15 hits)

Bird *Escherichia coli* O157 (31 hits)

Amphibian *Escherichia coli* O157 (6 hits)

Frog *Escherichia coli* O157 (2 hits)

Decisions to include or exclude studies were made as follows:

- Studies of prevalence in wild animals being kept in non-native setting (e.g., zoos, pets, semi-domesticated herds) were not included. The exception to this was inclusion of samples collected from animals at wildlife rehabilitation centers. Such studies were included provided the methods stated that the samples were collected within a short period of time after arrival (three days or less) and that cages were sanitized between animal housing.
- In general, studies that reported results for pooled samples for which species included was not known were not included. Exceptions were made for flies which are typically tested in pooled samples.
- When methods failed to eliminate risk of cross contamination of samples, studies were not included (e.g., samples collected from traps or feeding station and site not cleaned between sample collections).
- If the animals tested were likely to be kept in a much different condition than those typically found in a farm environment, results were not reported (e.g., stray dogs with diarrhea in Trinidad).
- Unless a study was judged by experts in the field (consulted as members of our technical advisory committee, or as peer reviewers for the manuscript in preparation) to be landmark study, studies testing for pathogens in meat were not included.
- Because the compilation of the data represents what is possible in terms of animals shedding *E. coli* O157 and other pathogens in their feces, studies including samples collected from other environments (e.g., outside the U.S.) were included.
- Studies reporting virulence factors detected in samples tested for *E. coli* O157 were not included.
- Any references that met the above criteria but did not appear in the results of database searches, but were located by other methods (directed by researchers, found as citations in other works) were included.

Additional detail and citations for pathogens in wildlife

- Many studies, particularly with reference to birds, require careful interpretation because samples are taken from fecal deposits of unknown age, origin and exposure to contamination after deposition (e.g., Craven *et al.*, 2000).
- Some mammal samples are collected without full knowledge of the age, likelihood of contamination (or disappearance of pathogen) post deposition (e.g., Hancock *et al.*, 1998).
- Contamination of fecal material by dust (common in livestock environments in which Craven *et al.* samples were collected) is possible (Miller *et al.*, 2008). There is evidence that *E. coli* O157:H7 in some fecal material may actually increase after deposition (Feare, *et al.*, 1999), and that environmental conditions influence the survival of *E. coli* O157:H7 in fecal material (Wang *et al.*, 1996).
- A single study may be widely cited as justification for a food safety guideline. In some cases, careful review of the research methodology and the authors' conclusions show that they do not support the guideline as developed (e.g., Gray *et al.* 2007; Jay *et al.* 2007).
- Studies conducted in laboratory settings using levels of imposed contamination far greater than are likely to occur in field settings must be interpreted with great caution. What is possible to create in laboratory settings may not reflect what is likely to happen in field conditions. Kudva *et al.* (1998) caution that *E.*

*coli* O157:H7 may survive longer in laboratory studies meant to mimic field conditions than it does in actual field conditions.

- Notably lacking from the data set is adequate consideration of the prevalence of pathogens in reptiles, amphibians, and invertebrates. *Salmonella* transfer from pet reptiles and amphibians is common (Richards *et al.*, 2004), but these are reptiles kept in environments completely unlike those found in field settings; extrapolation of this data is inappropriate in the absence of further study. Many current food safety measures guide growers to minimize the presence of frogs (RCD, 2007; RCD 2009).

Pathogens and filth flies

- While not generally classified as wildlife, flies may be important vectors for some pathogens. Filth flies (flies that breed in feces and other organic refuse) have been found to carry *E. coli* O157:H7 and *Campylobacter* in a turkey raising operation (Szalanski *et al.*, 2004), *Salmonella* in a greyhound dog kennel (Urban and Broce, 1998) and *E. coli* O157:H7 on cattle farms (Iwassa *et al.*, 1999). Ongoing research is examining the potential for these insects to transmit human pathogens to produce (see Appendix K). In discussion of the importance of dispersal data, flies provide a good example. Some food safety standards call for a minimum distance from cattle operations (Schmit, 2006). The above studies all verify that flies may be capable of vectoring pathogens of concern, but they give no specific information on distances the flies are likely to travel. Without this information, distances from animal operations prescribed by safety standards to reduce fly contact are speculative.

Additional details from Jay *et al.* 2007 study described in Part III

- Defined the study area in an area from which contaminated spinach had been implicated in a recent *E. coli* O157:H7 outbreak.
- Established two trap sites in the area and collected fecal samples from live caught feral hogs. Also tested cattle feces, cattle water troughs, surface waters, sediments, well water and collected fecal samples from several other wild (bird, coyote, deer) and domestic (dog, goat, horse, sheep) animals from the area determined to be a home range for the feral swine captured in the traps.
- Used remote-sensing cameras and field observations to estimate population size and movement patterns of feral swine. Details of the environment that help gauge risk of cross contamination from sources to produce were noted and discussed. For example, it was noted that while the crop production area was separated from the 2,000 range cattle grazing area by a wire fence, swine could access the crop field via gaps under the fence created by erosion and rooting behavior. Swine were observed in the crop field, as were tracks and feces.
- Landscape features relevant to the movement of surface waters were noted, and it was determined that risk of contamination by surface runoff from range land was minimal (due to topographical features).
- Irrigation water drawn from a well was negative for E.coli O157:H7, but personal communication from an individual familiar with the site revealed that an older agricultural well at the ranch might be vulnerable to surface water contamination.
- In addition to the extensive documentation of the landscape in which the contamination event is thought to have occurred, the authors provided information regarding the specific strains of *E. coli* O157:H7 detected in each source, giving further evidence to help detect the path by which it may have moved.

- Concluded that the avenue of contamination remains unclear. Further, they acknowledge that the feral swine, and other animals in the test area, may be sentinel species (indicators of contamination) rather than primary sources of it.

Additional details from Cooley *et al.* (2007) study described in Part III.

- used an evolving methodology (Multi-Locus Variable-number-tandem-repeat Analsysis (MLVA)) to trace potential fate and transport of *E. coli* O157:H7.
- Fecal (including wild pig), soil, sediment, plant and water samples were collected from a wide study area, with specific collection sites noted.
- Water samples were collected by allowing a collection vessel to remain in the water source for a period of five days rather than a composite sample at one time.
- Tracing the individual strains of *E. coli* O157:H7 through the landscape samples, the authors conclude that contamination of produce almost certainly involves multiple sources and methods of transport.

Supplemental Information About Pathogen Prevalence In Cattle

- Cows carrying pathogenic bacteria may not display symptoms, but may still shed the pathogens in manure (Wray and Davies, 2000; Sargeant *et al.*, 2000).
- Herd management for animal health may not fully control pathogen reservoirs. Since as little as 10 to 100 cells of *E. coli* O157:H7 can lead to infection (Armstrong *et al.*,1996; Nataro and Kaper, 1998), even low levels of pathogen shedding in manure leads to risk for surrounding fresh produce growers.
- While animals carrying *E. coli* and other pathogens may not be immediately threatened, elimination of the pathogen is generally a goal of good animal husbandry and is critical to minimize contamination of beef products (Pedersen and Clark, 2007).
- Soon after the first *E. coli* O157:H7 outbreak was recognized, cattle were identified as a critical source for the pathogen (Montenegro *et al.*, 1990; Cobbold and Descmarchelier, 2000; Kobayashi *et al.*, 2001; Yilmaz *et al.*, 2002).
- Whether cows are the primary reservoir for the bacteria, or an incidental host is not fully understood (Hancock *et al.*, 1998).
- Though other farm animals have been shown to harbor *E. coli* O157:H7 including poultry (especially chicks), lamb, and pigs (Chapman *et al.*, 1997; Beutin *et al.*, 1993; Johnsen *et al.*, 2001), the guts of ruminant animals (cows and sheep) are thought to be the most important source of *E. coli* O157:H7 (Brabban *et al.*, 2004).
- Pooling data from 23 separate studies, the USDA estimated that within herd prevalence of *E. coli* O157:H7 for cattle of all types (calves, beef and dairy) ranges from 1.3%-9.5%, while the percentage of herds with at least one infected animal ranges from 22-100% (USDA, 1997).
- According to the USDA's National Animal Health Monitoring System 1996 Dairy Study, 30.9% of dairy cattle being culled (going to slaughter) were shedding *E. coli* O157:H7 (Wells et al, 1998).
- Dairy cattle also frequently carry other important pathogens. In a 2002 study of dairy herds, 7.3% of cows shed *Salmonella* spp., with 31.3% of herds sampled having at least one cow shedding *Salmonella* spp.

*Campylobacter* was isolated in 51.4% of cows sampled, and was found in at least one cow in 97.9% of the herds (USDA/APHIS, 2003).

- In beef cattle, as many as 80% of feedlot pens tested positive for *E. coli* O157:H7 (Khaitsa *et al.*, 2003).
- Seasonal differences in pathogen loading are commonly observed. Some estimates state that 30% of all cattle in U.S. shed *E. coli* O157:H7 in their feces, and during the summer this may be as high as 80% in feedlot animals (Elder *et al.*, 2000; Zschock *et al.*, 2000)
- Veterinary and animal science experts are currently exploring a range of management variables that may impact pathogen prevalence and persistence in animals. Among these variables are: diet, sanitary practices, birds in feedlots/dairy farms, use of pharmaceuticals, etc. (Brabben *et al.* 2004; LeJeune and Wetzel, 2007; Reinstein *et al.*, 2009; Wells *et al.* 2005)
- Epitopix LLC, a Minnesota veterinary pharmaceutical company, has received a conditional license from the U.S. Department of Agriculture to develop a vaccine that shows promise for use in beef cattle to reduce the prevalence of cattle shedding *E. coli* O157:H7 (Finz, 2009).

Supplemental Information About Cattle Production in the Central Coast Region

- Cattle ranching is an important land use in the Central Coast with over 2.7 million acres of rangeland in the region and over a million acres of rangeland in Monterey County alone (Central Coast County Crop Reports for 2007).
- In 2007 there were over 1,800 cattle operations in the Central Coast region with over 250,000 cattle and calves (US Census of Agriculture 2007, Central Coast County Crop Reports for 2007).
- These operations include both cow calf and stocker cattle grazing operations.
- Stocker grazing cattle has increased in Monterey County over the past 10 years (Monterey County Crop Reports 1997, 2007).
- Cattle in the Central Coast are often transported in from other areas in the Western U.S. for winter grazing.
- There are a total of 11 dairies in the Central Coast region, distributed among the counties as follows: San Benito (4), Santa Clara (1), Santa Cruz (1), Monterey (3), San Luis Obispo (1), Santa Barbara (1), and San Mateo (0). Source:http://www.cdfa.ca.gov/dairy/pdf/Annual/2008/stats_2008_year_report.pdf
- There are only a few feedlots in the Central Coast region.

Supplemental Information on Manure and Compost

- Raw manure is no longer applied to cropped fields in the Central Coast region.
- In the Central Coast region, several composting operations use manure from regional feedlots, dairies, and other livestock operations.
- Both organic and conventional crop growers in the region use compost.
- Regional landscapers and golf courses also use compost.

Regulation and monitoring of compost processes and finished product

Compost products are regulated by the Department of Resources Recycling and Recovery (CalRecycle). Composting operations regulatory requirements are described in Chapter 3.1 of Title 14, Natural Resources—Division 7, CalRecycle. Required monitoring of the production process focuses on temperature and aeration status of the composting materials, while certification of the finished product includes testing for pathogen content. Certification of finished product is available via the US Composting Council Seal of Testing Assurance (STA) program.

(See http://www.ciwmb.ca.gov/Regulations/Title14/ch31a5.htm#article6 for further details.)

Organic growers must use compost that is produced and certified according to the standards described in the National Organic Program (NOP Section 205.203(c)(2)). The Organic Materials Review Institute (OMRI) certifies materials as appropriate for use in organic production systems by similar monitoring of production conditions and testing of final product. Compost products that have passed review according to NOP standards may use an OMRI ListedTM symbol. Finished product is not certified as "organic", but rather is registered as Allowed (for unrestricted use) or Regulated (when certain restrictions such as time to crop harvest may be required). (See http://cwmi.css.cornell.edu/compostfs2.pdf for more information.)

Potential for contamination of properly processed compost material exists when equipment used to load or store fresh manure is subsequently used with finished product. To minimize this risk, education of compost processing facility employees is essential (Dr. David Crohn, personal communication).

2008 Central Coast Cattlemen's Grazing Lands Non-point Source Approach

Excerpts from unpublished document:

*Statement of Purpose:*

As a result of increased surface water quality monitoring, certain water bodies on the Central Coast have been deemed impaired for a variety of constituents. Some constituents such as pathogens or sediment have been assumed to be associated with cattle grazing activities. Subsequently, in 2006 The Central Coast Regional Water Quality Control Board (RWQCB) began dialog with the Central Coast Cattlemen regarding their impacts to water quality while simultaneously conducting an active assessment of the potential for water quality impacts due to grazing and livestock operations.

In response to discussions with RWQCB, and as the Central Coast Cattlemen take seriously their land stewardship mission; this document was created as a basis for the application of appropriate grazing management measures for California's Central Coast region rangelands with respect to protecting or enhancing the region's water quality. The primary goals of these measures are to:

1. Maintain and or enhance the quality of the region's water resources, stressing prevention rather than costly fixes and monitoring.
2. Stress voluntary participation through education, technical assistance, incentives and emphasize the benefits of such an approach.
3. Reduce conflicting regulatory authorities, fees and permit requirements in order to encourage implementation of management measures that will produce net water quality and other environmental gains.
4. Focus implementation and monitoring at the ranch and/or watershed level.
5. Encourage research to assess water quality impairments, determine causes,and develop appropriate monitoring techniques and solutions.
6. Balance legal requirements with the need for site-specific flexibility and economic feasibility for rangeland managers.
7. Identify gaps in information that may prove critical for taking a science based and economically sustainable approach to protecting water resources, particularly with respect to pathogenic loading.

*Measures for managing nutrients and potential pathogenic contamination from livestock:*

1. Most importantly, keep 100% of the soil covered 100% of the time. Though this may not be possible, it is a critical management goal if biologically active soils are to be produced and losses of nutrients are to be minimized. For purposes of definition, "covered soil" means that if a raindrop were to fall it would hit plant material before it hit the soil.
2. Time of use, relative to season, vegetation growth, crop production patterns and weather, can be very effective and of minimal cost in preventing pathogen movement onto crops.
3. Communication between farmers and livestock mangers can be effective to this end as well.

4. Keeping livestock from loafing and over utilizing areas immediately adjacent to cropland can effectively reduce the deposition of manure, help minimize soil compaction and maintain healthy plant communities in order to maintain infiltration and filtering capacity. If supplemental feeding is utilized during the fall and winter months, feeding should occur away from sensitive areas in order to reduce the deposition of excessive fecal material, soil compaction and loss of vegetative cover/filtering capacity.

5. The installation of alternative drinking sources, where feasible, can be extremely effective for minimizing livestock use of sensitive areas and streams. The development of springs and seeps away from sensitive crops and providing for additional impoundment and troughs can help minimize livestock use and thus reduce the risk of pathogenic contamination.

6. Salt and mineral supplements should be placed in locations and at distances adequate to protect sensitive areas.

7. Use of sensitive habitat by wildlife, particularly wild pigs, should be monitored. During the dry season, pigs like to wallow in streams and wet areas and may be drawn from rangelands into irrigated crop land on a seasonal basis, depending on water availability and foraging opportunities. Hunting pressure or trapping may be effective at moving pigs away from sensitive areas or where there is concern about their access directly into cropland.

8. While expensive and impractical in many Central Coast rangeland settings, the use of fencing may be an appropriate alternative for excluding livestock from areas directly adjacent to sensitive crops, and to create buffers between areas of particular concern and livestock. Alternatively, the appropriate selection of crops less sensitive to pathogenic contamination in those areas impacted by wildlife or adjacent land uses can also minimize risk.

9. Pens or small pastures used to confine livestock that are in close proximity to sensitive crops, particularly those used during periods when there is significant hydrologic activity, should be located in areas where they have drainage that provides adequate filtering capacity to protect sensitive areas.

10. Application of inorganic fertilizers on rangeland is not commonly practiced throughout the Central Coast. However, if fertilizers are applied, timing of applications and consideration given to runoff patterns should dictate appropriate use.

## Appendix
## Supplemental Information Relating to Conservation Practices

Value of non-crop vegetation and wetlands to improve water quality

- Using non-crop vegetation for "bioassimilation" of pollutants is held to be the most sustainable, cost-effective, and ecologically sound approach to address problems of diffuse pollution from agricultural activities (Osborne and Kovacic 1993).
- Vegetative buffers such as filter strips, vegetative barriers, and buffer strips can slow, retain, and metabolize pollutants (Dabney *et al.* 2006).
- Buffers restrict pollution by reducing movement, increasing sedimentation, increasing uptake by plants, and increasing microbial activity (Locke *et al.* 2006).
- Buffers less than 1 m wide can trap significant amounts of sediment (Van Dijk *et al.* 1996, Blanco-Canqui *et al.* 2004).
- Vegetative buffers retain nitogen through both vegetative biomass uptake and bacterial denitrification (Haycock and Pinay 1993).
- A review of studies on vegetative buffers indicates that reduction of nitrogen ranges between 40–100% in subsurface water and between 73–98% in surface water (Osborne and Kovacic 1993)
- 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).
- 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).
- 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 nitrogen gas, thereby reducing water quality issues (Schaafsma *et al.* 2000, Hey 2002).

- Efficiency of nutrient trapping depends on the rate of flow, 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; Tate *et al.*, 2008; Knox et al, 2008).
- Contamination in overland flow may be reduced by filtration through perennial forage and/or grasses. One study tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California (Tate *et al.* 2006). Scientists used known quantities of *E. coli* and measured transport in surface water run-off. 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 may be specifically designed to reduce *E. coli* transport.
- A review of 40 field trials indicates that vegetative systems within waterways, basins, or ditches can achieve significant pollution reductions, including pathogenic bacteria (Koelsch *et al.* 2006). Other studies indicate that fecal coliform reductions greater than 90% are regularly observed from vegetated treatment systems (Kadlec and Knight 1996).

Value of non-crop vegetation and wetlands to reduce pathogens in water

- Constructed wetlands have been demonstrated to be highly effective in reducing the presence of pathogenic bacteria and are 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).
- Large as well as small-scale constructed wetlands can reduce levels of fecal coliforms by up to 97% (Nokes *et al.* 2003).
- Scientists have tested the effectiveness of constructed wetlands at removing specific pathogenic bacteria. Within a 23–52 hour wetland residence time *Salmonella* levels can be reduced by 93–96% (Hench *et al.* 2003).
- One study reported a 96% reduction in *Salmonella* in wastewater from a pig farm after passing through a constructed wetland (Hill and Sobsey 2001).
- Constructed wetlands have been shown to remove 95% of pathogens and indicator organisms (Greenway 2005).
- Surface-flow constructed wetlands with a high diversity of macrophytes can reclaim water and produce effluent meeting microbial standards for agricultural irrigation (Greenway *et al.* 2005). Heavily vegetated wetlands also have a higher removal rate of harmful bacteria compared to non-vegetated wetlands (Nokes *et al.* 2003).
- Vegetated treatment systems which are primarily used to enhance environmental quality, may be designed specifically to reduce harmful pathogens in agricultural settings. For example, constructed wetlands can be designed with specific depths, flow, and vegetation to maximize the removal of pathogens (Greenway *et al.* 2005).

## Appendix K
## Ongoing and Suggested Research

Ongoing Research Projects of the Partners in Research Program

The following are research projects currently funded by the Partners in Research Program jointly administered by the California Leafy Greens Research Program and the Center for Produce Safety at UC Davis. The following projects are funded March 2009 to March 2010 with data expected shortly thereafter.

- Contribution of phyllosphere microbiota to the persistence of *Escherichia coli* O157:H7 ATCC 700728 on field-grown lettuce Maria Marco, PhD, University of California, Davis in collaboration with WIFSS Associate Director Dr. Linda J. Harris

- Fly reservoirs of *E. coli* O157:H7 and their role in contamination of leafy greens
  Astri Wayadande, PhD, Oklahoma State University

- Food safety risks associated with sheep grazing in vegetable stubble fields
  Bruce Hoar, DVM, PhD, University of California, Davis

- Minimizing pathogen transference during lettuce harvesting by optimizing the design of the harvesting device and operation practices
  Yaguang Luo, PhD, USDA, ERS

- A high-throughput, culture-independent approach to identify index and indicator species for *E. coli* O157:H7 contamination

  Gitta Coaker, PhD, University of California, Davis

- Survival of attenuated *Escherichia coli* O157:H7 ATCC 700728 in field-inoculated lettuce
  WIFSS Associate Director Dr. Linda Harris, PhD, University of California, Davis

- Comparison of surrogate *E. coli* survival and epidemiology in the phyllosphere of diverse leafy green crops.
  Trevor Suslow, PhD, University of California, Davis

*For More Information about the above projects contact:*

Bonnie Fernandez, Executive Director
Center for Produce Safety
Phone: (530) 757-5777

Mary Zischke, CEO
California Leafy Greens Research Program
Phone: (831) 424-3782

National Research Initiative of the USDA-Cooperative State Research, Education and Exentension Service

Ecology and epidemiology of *Escherichia coli* O157:H7 in fresh produce production regions on the central California coast
Start Date: 2007 End Date: 2010

Study Objective:

We hypothesize that vertebrate populations function as a key source of *E. coli* O157:H7 (EcO157) contamination of watersheds where leafy greens and other leafy vegetables are grown; that climate, landscape attributes, and irrigation practices correlate with increased risks of EcO157 and commensal *E. coli* contamination; and in-field contamination of leafy greens plants with EcO157 relates to combinations of production practices and environmental risk factors in the Central California Coast, specifically, the San Juan Valley region. The major objectives of this project are to (1) quantify environmental loading by vertebrate sources, especially feral swine, (2) characterize the predisposing conditions for hydrological transport of EcO157 and *E. coli* to leafy green fields, (3) identify the in-field mechanism(s) of contamination of leafy greens, and (4) develop and disseminating educational materials for growers of fresh produce and the livestock community about microbial water quality, potential impacts on down-stream stakeholders, and effective good agricultural practices for improving water quality and produce food safety.

Study Approach:

To conduct an in-depth longitudinal study that identifies the key biotic and abiotic processes that sufficiently load, then hydrologically link and disseminate, primary environmental reservoirs of EcO157 within and between leafy greens fields, resulting in bacterial contamination of this raw agricultural commodity. For each node (vertebrate sources, water, soil, leafy greens) of the system, the cooperator will collect a detailed set of co-variates that will be used to identify critical control points, points of environmental amplification, and management practices that either elevate or decrease the risk of in-field contamination and dissemination of EcO157 on leafy greens. Samples collected, will be analyzed by the ARS lab for presence of EcO157 and strains isolated will be genotyped by Multi-Locus Variable number tandem repeat Analysis (MLVA) and Pulsed Field Gel Electrophorsis (PFGE) for purposes of source-tracking information, and thus, pinpointing the mechanisms that link and disseminate vertebrate sources of EcO157 within and between fields of leafy greens. Documents SCA with UC Davis.

Scientists involved in the study:

Rob Mandrell, microbiologist; Michael Cooley, microbiologist, USDA-ARS-WRRC-PSMRU; Rob Atwill, epidemiologist and veterinary medicine specialist and Michele Jay-Russell, veterinary food safety specialist, Western Institute for Food Safety and Security, School of Veterinary Medicine, UC Davis; Ken Tate, rangeland hydrologist, UC Cooperative Extension rangeland, UC Davis Department of Plant Sciences; Royce Larsen, UC Cooperative Extension area natural resource watershed advisor, San Luis Obispo and Monterey Counties.

Water Quality and Food Safety Program

Field trials testing the effectiveness of various management practices in reducing nutrients, sediments and bacteria in irrigation tail water. Two main field trial programs are funded from January 2007 to January 2010. Principal researchers are Michael Cahn, PhD, University of California Cooperative Extension, Salinas; Marc Los Huertos, PhD, California State University, Monterey Bay and Trevor Suslow, PhD, University of California, Davis.

- Grassed Waterway & Polyacrylamide Field Trials: Evaluate effectiveness of vegetative and non-vegetative management practices to reduce nutrients, sediments, and bacteria in irrigation tail water.
- Vegetated Treatment System Field Trials: Evaluate the influence of Vegetated Treatment Systems (designed to assimilate nutrients and pesticides) on *E. Coli* and coliform bacteria concentrations.

For more information about this program, please contact:

Kay Mercer, Executive Director
Central Coast Agricultural Water Quality Coalition
750 Shannon Hill Dr
Paso Robles Ca 93446
(805) 208-8039 cell

Suggested Research

The production of this report also highlighted areas that are important for further research. An important next step would be to expand beyond the study of pathogens to include ecological impacts of on-farm management practices. This research would add support to concerns about how management practices impact not only food safety but also ecological health. Management changes also generate myriad economic costs and benefits. In addition to research suggested by Bianchi *et al.* (2008) this report illustrates the need for research to explore additional topics and questions:

*Environmental impacts of on-farm management practices. For example:*

- What are the impacts on fish, mammals, birds, and other wildlife?
- What are the impacts on the quantity and quality of freshwater?
- What are the impacts on human health via soil, water, and air?
- Do management practices interact to create synergistic effects?
- What are the impacts at the larger scale, e.g., watershed and landscape?
- What changes to the design and implementation of conservation practices can maximize contribution both to food safety and environmental goals?

*Economic impacts of on-farm management practices. For example:*

- What are the direct and indirect costs of various practices?
- What are the direct and indirect benefits of various practices?
- How do costs and benefits vary over the short- and long-term?
- How are costs and benefits distributed?

## Appendix I: Supplemental Information on Co-Management and Key Issues

### Liability and Litigation and Insurance

- Insurance has traditionally been a means to spread risk throughout an industry or market. According to food safety attorney Bradley Sullivan of Lombardo & Gillis, the insurance industry has reacted to the trend of extending liability along the distribution chain (Pers. Comm.).
- As liability and litigation have moved increasingly toward farms, insurers have raised premiums charged to growers, included exceptions and restrictions for contaminated produce in coverage written, and have stopped underwriting policies to insure growers they perceive to present high liability risk.
- Some insurance companies have stopped offering insurance to the California produce industry.
- A lack of affordable coverage represents a potentially lethal blow to growers, given that they must maintain coverage in order to borrow capital and otherwise run a business.
- Self-insurance, higher "retentions" (akin to "deductibles" in personal insurance lines) and industry combining to form their own "insurance carriers" are possible reactions to changes in policy availability.
- Although liability and litigation reached the growers, they may extend further. Many growers lease lands owned by others. These owners may face litigation risk for what occurs on lands they own but do not manage.

### Irradiation and Possible Legal Implications

- On August 22, 2008, the FDA issued new regulations allowing for irradiation of spinach and iceberg lettuce. The new regulation came in response to a petition by The National Food Processors Association on behalf of The Food Irradiation Coalition.
- The FDA rule provides for the "safe use of ionizing radiation for control of foodborne pathogens, and extension of shelf-life, in fresh iceberg lettuce and fresh spinach." (FDA 2008).
- Public acceptance of the technology is not clear, and security, volume, and cost issues abound. Also, scientific questions remain about how eliminating all microflora may potentially exacerbate contamination "downstream" of irradiation.
- The FDA ruling is likely to have long-term implications. On one hand, it represents movement toward a much-desired "kill step" for foodborne pathogens that could reduce illnesses and lawsuits. On the other hand, approval of irradiation for certain leafy greens may exert *de facto* pressure on growers/handlers to use the technology or subject themselves to legal risk.

### Illustrative Examples of Inconsistencies in Food Safety Standards

(From grower interviews in 2009)

Grower 1 states that auditors from processors and buyers are not consistent: the auditors **"change their minds depending on the market."** He describes how some pigs ran through his field of lettuce. When the processor came to harvest half of it they marked off 40 feet on all sides of the pig tracks and harvested the rest. They came back for the rest of the field the next week, but in the meantime a hurricane had hit Mexico and destroyed the crop there. The buyer was short on product and cut the lettuce within 2 feet of the same pig tracks, violating their own standards as well as the LGMA standards. He explains why the growers are powerless in these situations: **"there is a short list of people you can grow for and some of them own the land you farm."**

Grower 2 says auditors for the shippers are inconsistent and change their minds on what is acceptable. He explains one experience he had where a large processor said they would not take any crop from a ranch due to "the potential for amphibians." So they made a deal with someone else to harvest it. But later the same processor changed their mind and harvested it anyways. He says: **"when the market is good they will take it, their own standards are flexible and if it is clean they will take it."** He says: **"on the other side, if the market is bad they will find an excuse not to take it. Food safety is used as a tool not to accept some crops due to market conditions."**

Grower 3 had a contract with a large processor for lettuce on two fields. The first field was ready to harvest but was rejected due to animal intrusion (deer tracks). The second field was not mature yet, but they rejected it as well because of its close proximity to the deer tracks. At this time the price for lettuce was low and the market was flooded. They disced the first field but left the second one to find another buyer. However, the market suddenly improved and the same processor called back wanting to harvest the second field they already rejected.

Grower 4 says that processors are inconsistent with their standards: **"if they need a crop bad, they will take it."** He says that in certain cases: **"they will look the other way."** He explains that once the processor banned a ranch, but then when they really needed product they bought produce from that ranch anyways.

Grower 5 has not recently experienced any inconsistency with the buyers because he does not sell to processors anymore. He says they used to have problems when they sold to a large salad processor: **"We were in a processed deal with XX and got out because their excuses were due to the market not food safety. In a good market they would trip over themselves for garbage crops."**

Grower 6 shares that once a shipper rejected a whole ranch for vague food safety reasons. She knew from someone who worked there that the shipper had too much product and was looking for excuses to reject the crops. Then someone else took the crops right away- there was no problem. She says: **"the market drives the standards. If the market is really good it is amazing what they will turn their heads to."**

Grower 7 says that shippers change their standards due to changes in the market. He explains that **"if a shipper is short on lettuce or they can get a good price for it they have a tiny buffer around a gopher hole."** He says **"when the market is bad or they have too much product they flag off huge areas or reject entire fields for no reason."** He says that food safety is used as an excuse in many cases.

Industry Movement into Value Added Products

- Produce industry employees indicate that water used to wash lettuce or other greens in the processing plant is in many cases used to wash multiple batches, thereby potentially contaminating a larger volume of product and potentially leading to more illnesses per outbreak.
- Bacteria can enter into leaf tissue during washing making the leaves impervious to later surface washing. Processing can damage leaves, and damaged leaves are associated with increased risk of human pathogen contamination (Gorny *et al.* 2006).

Estimating a Connection between Pocessed Product and Foodborne Illness Outbreaks.

Any effort to demonstrate a link between processed product and outbreaks of foodborne illness must take into account numerous important considerations:

- It should examine a long time period, going back at least to 1996 when the CDC's modern surveillance system began, and preferably ten years farther.
- It should plot annual variation rather multi-year average to see if the lines move in tandem (possible correlation).
- It should extract the subset of annual foodborne illnesses attributable to leafy greens and the portion caused by bacteria of particular concern such as pathogenic E.coli.
- It should analyze annual per capita trends, specifically pounds of leafy greens consumed per 100,000 people, and foodborne illnesses per 100,000 people.
- It should plot and compare annual percentage changes.
- It should explore potential differences in the way consumers treat bagged product, for example eating it after the expiration date or being more able to identify the source of an illness because the container came with a company name printed on it.
- Even if future research were to incorporate these suggestions and take several other appropriate steps, attempting to demonstrate a causal relationship between bagged product and foodborne disease outbreaks would remain a complex and challenging task.

The Produce Safety Project (PSP), an initiative of The Pew Charitable Trusts at Georgetown University, commissioned this report from The Nature Conservancy and is responsible for its content.

PSP would like to thank Dr. Jeffrey LeJeune, of The Ohio State University, and Dr. Cliff Zukin, of Rutgers University, for their review of this report. The views in this report do not necessarily reflect the views of The Pew Charitable Trusts or of the reviewers.

*Revised May 25, 2010*