

Research Priorities for Coordinating Management of Food Safety and Water Quality

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Efforts to exclude disease organisms from farms growing irrigated lettuce and leafy vegetables on California's central coast are conflicting with traditionally accepted strategies to protect surface water quality. To begin resolving this dilemma, over 100 officials, researchers, and industry representatives gathered in April 2007 to set research priorities that could lead to effective co-management of both food safety and water quality. Following the meeting, research priorities were refined and ordered by way of a Delphi process completed by 35 meeting participants. Although water quality and food safety experts conceptualized the issues differently, there were no deep disagreements with respect to research needs. Top priority was given to investigating the fate of pathogens potentially present on farms. Intermediate priorities included characterizing the influence of specific farm management practices on food safety and improving our understanding of vector processes. A scientific subdiscipline focusing on competing risks is needed to characterize and resolve conflicts between human and environmental health.

WHEN a deadly outbreak of *Escherichia coli* O157:H7 was linked to a 15 Aug. 2006 spinach harvest, it drew intense attention to the region's growers and packers. On 8 September, several cases of hemolytic uremic syndrome (HUS) alerted Centers for Disease Control and Prevention (CDC) scientists to a possible outbreak. This information was immediately shared with the CDC's PulseNet, a nationwide network that coordinates local, state, and federal laboratories during food safety emergencies. PulseNet confirmed the outbreak on 12 September and located its source on 15 September. The identified packer, Natural Selection Foods, immediately issued a costly nationwide recall (Porter and Lister, 2006). Soon the contamination was narrowed to ready-to-eat Dole Baby Spinach. By January, the CDC had confirmed three deaths and 205 illnesses, many severe, from the August *E. coli* contamination. In a report the following March, officials concluded that there were two potential sources of contamination: (i) the mixing of ground water with contaminated surface water and (ii) vectoring by wildlife, most likely feral pigs (California Food Emergency Response Team, 2007; Jay et al., 2007).

California's central coast is ecologically diverse and rich in endemic plant and animal species (Davis et al., 2008). Tourists are attracted to the region's striking juxtapositions of natural and agricultural settings (Clay and Smidt, 2004), but its surface waters are widely polluted, and agriculture is listed as a major source of this pollution (Hunt et al., 2006; Los Huertos et al., 2006). Removal of water quality management practices (MPs) has the potential to undo decades of efforts by farmers and the state and federal agencies that have assisted them. Cover crops are the most commonly used water quality practice in the region. Other common water quality management practices include stormwater ponds, filter strips, grassed waterways, irrigation reservoirs, irrigation tailwater recovery ponds, hedgerows, riparian buffers and constructed wetlands, which also serve as exceptional wildlife habitat (Stuart et al., 2006).

In California's central coast, produce from large farms is generally contracted by large marketers or restaurant and supermarket chains. These organizations are enormously influential because they retain the right to reject crops that do not meet their requirements. These buyers are understandably risk-averse, having invested heavily in the reputation of their brands. At the time of the *E. coli* outbreak, farm

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Abbreviations: CDC, Centers for Disease Control and Prevention; DCM, distance-based ideal-seeking consensus ranking model; FDA, U.S. Food and Drug Administration; GAPs, Good Agricultural Practices; HACCP, Hazard Analysis and Critical Control Points; HUS, hemolytic uremic syndrome; MPs, management practices.

food safety guidance could be found in the 1998 U.S. Food and Drug Administration (FDA) Good Agricultural Practices (GAPs) guide (Food Safety Initiative Staff, 1998) and in a 2006 industry-sponsored supplement to the GAPs (Gorny et al., 2006). The 1998 GAPs states that all animals, “including mammals, birds, reptiles, and insects” can vector pathogens into produce. The 2006 amendment recommended reducing vegetation, harborage, and standing water near fields.

Before the outbreak, many buyers already required third party inspections of fields to certify GAPs compliance. Since the outbreak, many buyers have enforced very strict interpretations of the GAPs and crops have been rejected for reasons ranging from signs of deer to the proximity of frogs and tadpoles. Enforcement has been strictest in lettuce and leafy greens fields because packers have difficulty removing pathogens from the extensive surface area and overlapping structure of these vegetables. As part of the food safety effort, farmers are removing potential wildlife habitat areas near their fields when they conflict with food safety guidelines, destroying MPs previously installed to protect water quality. In the spring of 2007, a local Resource Conservation District surveyed 600 farmers and found that 89% of respondents had taken steps to exclude or eliminate wildlife from their fields. Farmers are using fences, poisons, traps, and bare ground buffers. Twenty-one percent of leafy green growers have already begun actively removing their water quality practices due to the food quality concerns of their buyers. The overwhelming majority of removals were from large farms (>202 ha) growing lettuce or leafy greens selling directly to shippers or packers. Practices targeted for removal have included tailwater recovery ponds and irrigation reservoirs, grassed waterways, filter and buffer strips, trees, and shrubs (RCDMC, 2007).

Materials and Methods

Risk management strategies for food safety and for water quality currently conflict. Vegetation used to stabilize soils and structures used to collect runoff can serve as habitat for wildlife that food safety officials suspect may vector pathogens into fields growing fresh fruits and vegetable products. Water quality officials are concerned that removal of water quality MPs will increase the export of nutrients, pesticides, and pathogens to regional surface waters. Coordinated management alternatives are clearly needed. As a first step toward co-management, in April 2007, over 100 specifically invited food safety and water quality leaders met for 3 days in San Luis Obispo, California to discuss research priorities needed to assure food safety while conserving water quality. The experts represented government, industry, and academia and were active at national, state, and regional levels. Organizers hypothesized that the food safety and water quality communities were largely uneducated as to each other's concerns, constraints, and motivating interests. The first half of the meeting, therefore, included basic information about water quality, food safety, and their co-management in central coast agriculture. During the second afternoon, small groups representing both constituencies visited area farms. Water quality leaders were asked to audit the farms from a food safety perspective and food safety experts were expected to assess water quality concerns. Assuming and describing a different

and unfamiliar set of concerns proved to be both challenging and enlightening for participants. The third day was spent discussing research and collaboration priorities. These priorities were further developed, post-conference, using an iterative evaluation procedure called the Delphi process (Adler and Ziglio, 1996). The Delphi was coordinated by an outside evaluator. Thirty-five of those who attended the meeting continued to participate through two additional Delphi iterations. The first iteration solicited responses to questions regarding coordinated management research priorities. These were then grouped topically by the evaluator, who also culled suggestions without general support. Separate groups emerged for (i) pathogen vectors and pathways, (ii) mitigation and management practices, and (iii) risk management. In the second iteration, Delphi participants ranked their preferences for each of these groups from among choices carried forward from the first round. Participants were also asked to select, from among the choices in all three groups, the five that would best meet their overall short-term needs. Consensus was determined using the optimization algorithm, DCM. The DCM was developed as a hybrid of two earlier approaches and has proven to be consistent with other methods. It is possible, however, that a different approach would generate different consensus rankings (Tavana et al., 2007). Although ranked, all of the listed priorities are considered important since the Delphi process culls minor priorities.

The purpose of this paper is to encourage efforts to develop practices that co-manage food safety and water quality, rather than to survey these vast and very separate literatures. Our approach is, therefore, to report the results of the Delphi process, and then to develop them by reporting research gaps suggested by the relevant literature. This compilation of research gaps is intended to invite discussion as well as to inspire scientific inquiry. Identification of a particular gap does not necessarily suggest that little work has been done on that topic. Rather, it suggests an area where research is needed that can be applied to the particular problem of co-management.

Results and Discussion

Research Priorities Related to Pathogen Vectors and Pathways

- 1.1. Compare the fate of pathogens introduced into barren and vegetated systems.
- 1.2. Characterize pathogen pathways during crop production, harvesting, and packing.
- 1.3. Characterize the persistence of pathogens in the growing and harvested crop.
- 1.4. Identify animals, including smaller mammals and/or birds, which are significant pathogen vectors.
- 1.5. Describe the fate of pathogens during storm flow and flood events, and associated with water control structures.
- 1.6. Describe how different husbandry techniques impact the occurrence of *E. coli* O157:H7 in cattle.
- 1.7. Determine how different range management strategies affect pathogen development and export.

These priorities reflect that sound co-management decisions require reliable information as to the impact of crop management

Table 1. Questions arising from research priorities related to pathogen vectors and pathways.

Research priority	Research questions
1.1. Pathogen fates: barren vs. vegetated systems.	Vegetated zones capture and infiltrate more coliforms than bare soils, but how do different soil, pathogen, and vegetation types contribute to pathogen capture and infiltration (Roodsari et al., 2005) and can this reduce ground water quality (Thiagarajan et al., 2007)?
1.2. Pathogen pathways: crop production, harvesting, packing.	Survival, treatment, and cross-contamination issues during packing have been characterized (Coetzer, 2006; Fonseca, 2006), but how do specific cultivar types, conditions, growth stages, pathogen densities, and soil textures, affect pathogen uptake or surface adherence (Solomon et al., 2006)?
1.3. Pathogen persistence: growing and harvested crop.	Though most available data are derived from controlled environments, <i>E. coli</i> O157:H7 appear able to survive from seedling stage to harvest under field conditions (Islam et al., 2004). How can the total influence of the many separate variables associated with field conditions best be applied to predict pathogen survival (Delaquis et al., 2007)? Are there agronomic practices that can improve sanitizer efficiencies post-harvest (Fonseca, 2006)?
1.4. Pathogen vectors: large and small animals.	Genetic fingerprinting can be used to track specific pathogen strains through different species (Liebana et al., 2003) and to identify sources of fecal contamination (Graves et al., 2007; Jiang et al., 2007; Meays et al., 2004; Somarelli et al., 2007). How significant are specific factors affecting the transmission of existing and emerging diseases through wildlife, livestock (Daszak et al., 2007; Gortazar et al., 2007), insects (Conn et al., 2007), and gastropods (Sproston et al., 2006)? How important or effective are rodent and reptile controls (Beuchat, 2006; Meerburg and Kijlstra, 2007)? Can habitat removal concentrate wildlife to an extent that promotes zoonotic diseases (Daszak et al., 2000)?
1.5. Pathogen fate: storm flows, floods, impoundments.	Now that genetic fingerprinting can be used to trace movement of specific pathogen strains in water (Cooley et al., 2007) and to quantify risk models (Ferguson et al., 2003), how do mass-balance and kinetics data for specific pathogens compare to those of indicator organisms, which have received more study (Ferguson et al., 2003; Pachepsky et al., 2006)?
1.6. <i>E. coli</i> O157:H7: influence of animal husbandry techniques.	Sound husbandry helps control zoonoses (Collins and Wall, 2004). How valid are simulation results suggesting that, used together, vaccinations, probiotics, modified diets, and hygiene improvements substantially reduce <i>E. coli</i> O157:H7 (Vosough Ahmadi et al., 2007).
1.7. Pathogen development and export: range management strategies.	<i>E. coli</i> and fecal coliforms can grow in fresh manure and survive longer under cool, shaded conditions (Meays et al., 2005; Van Kessel et al., 2007). Many water quality management practices (MPs) for range management are similar to those used for crops and similarly need work to quantify their effectiveness with respect to both pathogens and indicator organisms (Agouridis et al., 2005; Knox et al., 2007; Oliver et al., 2007). Also, can manure deposit patterns (Tate et al., 2003) be managed to reduce pathogen exports?

and water quality practices on pathogen behavior. Co-management requires a consideration of the impact of crop production and MPs on pathogen survival and movement (Priorities 1.1–1.3). The GAPs that conflict with MPs are intended to prevent vectoring by wildlife and water (Priorities 1.4 and 1.5). Respondents were also interested in animal husbandry and range management alternatives for source control (Priorities 1.6 and 1.7). There has been considerable research into pathogen vectors and pathways in packing houses (Priority 1.2), where conditions can be carefully designed to exclude and reduce them (Coetzer, 2006; Fonseca, 2006). Less is known about pathogen survival and transmission in the environment (Pachepsky et al., 2006; Yildiz, 2007). Existing information can be difficult to generalize quantitatively or transfer to other locations due to differences in local cultivation practices, ecology, terrain, hydrology, climate and weather, pathogen or indicator type considered, and measurement errors (Hamilton et al., 2006; Goss and Richards, 2007). Considerable work will be needed to resolve these complexities. Promising molecular fingerprinting techniques can track the movement of specific pathogen strains through complex environmental pathways, and these techniques are becoming more quantitative (Field and Samadpour, 2007). Table 1 summarizes some current questions suggested by the literature related to the pathogen vector and pathway research priorities.

Research Priorities Related to Mitigation and Management Practices

- 2.1. Identify the fate of pathogens captured through various conservation practices (e.g., grassed waterways, sediment basins).

- 2.2. Identify environmental conditions that promote survival and proliferation of pathogens in collected sediments.
- 2.3. Identify practices to help growers determine when and if sediment from catch basins can be safely reincorporated onto the field.
- 2.4. Identify practices to help growers determine when, and if, tailwater can be reintroduced to the field.
- 2.5. Determine the effects and feasibility of treating irrigation water and irrigation reservoirs to reduce pathogens.
- 2.6. Identify strategies to safeguard against importing pathogens in manure or compost.

The first four mitigation and management priorities, Priorities 2.1–2.4, arise from a need to understand and control possible impacts of water quality MPs on food safety. The last two, Priorities 2.5 and 2.6, consider the food safety impact of other agronomic practices, namely irrigation and soil amendment. Priority 2.1 is broadly written, overlapping Priorities 1.1, 1.4, 1.5, 2.2, and 2.4. Although an extensive body of literature describes pathogen behavior in oceans and estuaries, there is much less information with respect to fresh waters and sediments (Priorities 2.4 and 2.2) (Kay et al., 2007) and still less on sediment land application (Priority 2.3) where the literature focuses on chemical, rather than biological, contaminants (Burton, 2002). Affordable and appropriate risk-based sediment and tailwater quality standards, sampling protocols, tests, and management/treatment methods (Priorities 2.4 and 2.5) are needed that will allow water quality MPs to function while preserving food safety. The GAPs require proper composting before manures can be incorporated, but assurances are needed as to compost quality (Bihn and Gravani, 2006; LGMA, 2007). In-

Table 2. Questions arising from research priorities related to mitigation and management practices.

Research priority	Research questions
2.1. Pathogens fates: after capture with management practices (MPs).	A broadly stated priority. See Priorities 1.1, 1.4, 1.5, 2.2, and 2.4. Also, what is the likely fate of pathogens excreted within MPs by fauna that are visiting or inhabiting them? Can MP choices apply evolutionary pressures to pathogens that increase their persistence and their virulence (Walther and Ewald, 2004)?
2.2. Pathogens in sediments: growth and survival factors.	Sediments can protect and nourish certain pathogens, including <i>E. coli</i> O157:H7, and later release them to surface and ground water (Crabill et al., 1999; Gagliardi and Karns, 2000; Jamieson et al., 2004. To what extent can the parameters that determine the growth or survival of pathogens be quantified?
2.3. Pathogens in sediments: assessment for landspreading	<i>E. coli</i> may adapt to become native soil organisms (Ishii et al., 2006). What is the potential for pathogens to similarly adapt to inhabit sediments? How will sediment properties affect the export potential of sequestered pathogens (Guber et al., 2007; Kay et al., 2007)? Can tests and risk assessment approaches that consider pathogens in water or biosolids be adapted to determine when sediments are safe to use (Gale, 2005; Keeling et al., 2007; Shuval et al., 1997; Westrell et al., 2004)?
2.4. Pathogens in tailwater: assessment for irrigation.	Water reuse guidelines call for undetectable levels of viable pathogens in irrigation water applied to fresh vegetables, but what information is needed as to the presence and variability of human pathogens in tailwater to develop a risk-based approach for determining when or how testing should be conducted (Hamilton et al., 2006; Mena, 2006; USEPA and U.S. AID, 2004)? How should standards be adjusted to account for different irrigation methods (Bernstein et al., 2007; Bihn and Gravani, 2006)?
2.5. Irrigation water treatment.	What biological or energetic treatment methods, such as wetlands and ultraviolet radiation, are most practical and cost efficient for co-management (Berry et al., 2007; Hill, 2003; Karim et al., 2004)? What technologies are currently in use (Mena, 2006)?
2.6. Pathogens in manures and composts.	What manure properties, such as pH or fiber content, may contribute to pathogen persistence (Franz et al., 2005)? How much time is needed between a manure applications and harvests under specific management conditions (Bihn and Gravani, 2006)? Composting inactivates pathogens (Larney et al., 2003), but what industry quality control standards are needed to assure proper heating and avoid cross-contamination (Wichuk and McCartney, 2007)?

investigations suggested by the mitigation and management practices research priorities are summarized in Table 2.

Research Priorities Related to Risk Management

- 3.1. Specify proven practices that preserve food safety while improving water quality.
- 3.2. Develop risk assessment protocols that consider both food safety and water quality concerns.
- 3.3. Quantify the effectiveness of specific good agricultural practices in protecting food safety.
- 3.4. Identify a way to categorize and rank specific sources of risk.
- 3.5. Quantify the effectiveness of specific farm audit requirements in protecting food safety.

The food industry widely relies on Hazard Analysis and Critical Control Points (HACCP) to assure food safety. The HACCP applies seven principles, which (i) assess hazards, (ii) identify reliable safety measures (critical control points) (iii) assign acceptable performance parameters (critical limits), and then (iv) monitor, (v) maintain, (vi) verify, and (vii) document program performance. Significant hazards are designated by an appointed team that applies risk analysis to evaluate the likelihood and severity of all potential threats and propose mitigation strategies for threats deemed significant. Critical control points (CCPs) are central to the HACCP process. To be a CCP, by definition, an opportunity to eliminate a significant hazard must be both *essential* and *effective* (Early, 2002; Hurst, 2006). These criteria exclude agricultural fields that are both expansive and exposed. Interventions in the field are, therefore, referred to as *prerequisite programs* (Sperber, 2005). Prerequisite programs contribute to HACCP by reducing pathogens or other hazards, but are not established with the same rigor, nor are they relied

on to protect consumer health. Like MPs, they mitigate, but do not fully control, hazards.

Although fields and surrounding areas cannot serve as CCPs, food safety experts can draw on the HACCP principles to establish prerequisite programs. Each research priority related to risk management can be associated with a HACCP principle. Research Priorities 3.2 and 3.4 assess hazards and correspond to HACCP Principle 1. Priority 3.1 addresses control points, or Principle 2. Farm audits, mentioned in research Priority 3.5, are monitoring efforts, HACCP Principle 4, while research Priority 3.3 calls for verification of the GAPs, Principle 6. Note that the research priorities related to pathogen vectors and pathways and to mitigation and management practices support Principle 2 by providing guidance as to how essential and effective particular co-management alternatives will be.

These research priorities parallel the HACCP principles, but differ in that they call for mitigating two competing risks, food safety and water quality. The HACCP principles influenced the development of the very GAPs (Early, 2002) that are displacing water quality MPs. The HACCP has been vetted by food safety experts and is familiar to that community. It is beginning to be applied to water quality problems (Barry et al., 1998; Eliasson et al., 2001; Westrell et al., 2004; Committee on Sustainable Underground Storage of Recoverable Water, 2008). A sensible approach to co-management would be to adapt and apply HACCP. In its formal expression, HACCP is inappropriate for designating GAPs and MPs (Early, 2002; Bihn and Gravani, 2006), but the general structure of HACCP is promising. A revised Principle 1 will need to simultaneously consider food safety and water quality hazards, even when the likelihoods and magnitudes of the hazards differ. For example, some virulent human pathogens, such as *E. coli* O157:H7, may have a rare incidence rate in packed produce, but may have a severe impact when the

incidence occurs. Some water quality hazards, such as a sediment discharge, may be very likely, with a significant, but more moderate impact. A revised Principle 1 should provide a comprehensive consideration of respective risks, whether chronic or acute, and the degree to which each is exacerbated or improved by alternative management strategies. Unlike HACCP, the revision must also apply where control is variable or incomplete. Data will be needed to quantify various risks so that they can be compared and prioritized (Haas, 2002). Expectations of consumers, growers, businesses, and regulators will need to be considered in establishing the goals of the risk management process.

Critical Short-Term Research Needs

A long list of additional priorities emerged during the Delphi process. Respondents were asked to select their top five choices from the list but, because they were vetted differently, they are being reported separately as critical short-term needs. The top five priorities are ordered by the number of respondents selecting them.

- 4.1. Develop course materials on food safety-water quality co-management.
- 4.2. Develop a systems approach to water quality-food safety co-management.
- 4.3. Investigate the extent that beneficial microbial populations control pathogens in water, soils, on plants, and in manures.
- 4.4. Examine how pathogens respond to climate (solar radiation, temperature, humidity, wind, etc.).
- 4.5. Determine whether the probability that *E. coli* will move into food has been increased by regional developments (e.g., changes in riparian ecosystems, cultural practices, and processing.)

Respondent's first priority was for concrete information on steps toward co-management. University of California Cooperative Extension has 69 fact sheets available describing MPs (UC Cooperative Extension, 2008), and industry resources describe the GAPs (LGMA, 2007), but there is currently nothing available beyond a 2006 research brief (Stuart et al., 2006) that discusses co-management. The HACCP-derived co-management, described previously, could satisfy Priorities 4.2 and 4.4, and be used to generate guidance materials (Priority 4.1). The HACCP may also be complemented by regional multi-objective environmental impact and risk analysis research efforts (Payraudeau and van der Werf, 2005; Rossing et al., 2007). Regional impacts on wildlife and resulting effects on pathogen development and transmission should also be considered (Keesing et al., 2006).

Other microbes (Priority 4.3) may facilitate pathogen survival on plants, or competitively exclude them, but this is better understood for plant than human pathogens (Brandl, 2006; Heaton and Jones, 2008). Less is known about the influence of beneficial microbes in other environments, though probiotics served to livestock have been shown to reduce pathogen concentrations in manure, including *E. coli* O157:H7 (Doyle and Erickson, 2006). Probiotics have also been investigated for use in aquaculture (Balcazar et al., 2006). There has been considerable research into pathogen survival in different climates (Priority 4.4) (Jamieson

et al., 2002; Hill, 2003; Vidovic et al., 2007), but studies are needed where conditions are changing due to diurnal, seasonal, and weather variations. Thermal inactivation appears to follow Arrhenius kinetics (Hill, 2003; Amiali et al., 2006; Van Kessel et al., 2007), making use of temperature-adjusted time a possible option. Temperature-adjusted time facilitates the use of a common decay rate even when temperatures vary (Crohn et al., 2008; Downer et al., 2008), making inactivation rates easier to generalize. Approaches are needed that also incorporate radiation and moisture effects (Lang et al., 2007).

Changes in the prevalence and virulence of *E. coli* O157:H7 (Priority 4.5) are affected by many social, economic, ecological, and microbiological factors (Ali, 2004; Beutin, 2006; Caprioli et al., 2005). Locally focused interdisciplinary efforts will be needed to determine controlling factors under specific circumstances.

Conclusions

Results of the Delphi process indicate that co-managing food safety and water quality requires reliable information about the impact of crop management and water quality practices on pathogen transport and survival. This information can then be used to develop procedures that can jointly mitigate food safety and water quality hazards. Additional objectives related to animal husbandry, manure management, and composting were specifically excluded from the conference agenda by the organizing committee but still emerged as important to the participants.

Because there were 26 water quality respondents, and only nine food safety respondents, the combined results are weighted in favor of water quality. Water quality respondents may have responded in greater numbers because buyers and their auditors are encouraging food safety GAPs that negatively affect water quality MPs, rallying water quality interests. An unknown number of food safety participants also left the co-management meeting after its second day due to a scheduling conflict, and therefore missed a formative element in the Delphi process. Although the two groups conceived of the issues differently, no deep disagreements emerged. For example, the water quality group strongly favored research into the fate of pathogens captured by MPs, while food safety participants focused on the fate of the pathogens within captured sediments. Since most water quality MPs function by conserving sediments, the two groups were largely in agreement. As the Delphi process proceeded, respondents began to call for a systems approach to understanding, prioritizing, and managing farm processes to secure both food safety and water quality. There was overall consensus that research be applied toward identifying MPs that protect both water quality and food safety. Throughout the Delphi process, no respondents were able to identify an existing forum for gathering and disseminating coordinated management information. There was a decisive call for the formation of a Coordinating Council to fill these needs.

Faced with uncertainties, buyers have adopted what has been termed in other situations as a *precautionary principle*. This concept was thoughtfully expressed in the Wingspread Statement (Sandin, 2006) as "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even

if some cause and effect relationships are not fully established scientifically.” The precautionary principle has been vigorously assailed as an incoherent application of fear by government regulators against industry (Sunstein, 2005). Ironically, for the inter-industry case described here, private buyers are exercising a precautionary principle against private growers with collateral damage to government and private investments in water quality. It is encouraging that an October 2007 revision of the GAPs known as the “metrics” (LGMA, 2007), written by industry with government and academic input, is more measured and specific than earlier versions, identifying specific animals of concern and setback distances from areas of animal activity. Packers and shippers have agreed to enforce the metrics on a voluntary basis (Hoops, 2007). Buyers, of course, may accept the metrics or they can enforce more rigorous standards based on their own determination of prudent precaution.

To protect both public health and the environment, industry, government, and consumers are all eager for research that clearly identifies the negative or positive food safety effects of specific water quality practices. The USDA is already discussing a program similar to California’s metrics that would apply across the USA (Department of Agriculture Agricultural Marketing Service, 2007). Although the example developed here reflects conditions in California’s central coast, conflicts can be expected to spread as a global insistence on safe food and quality water develops.

Food-borne disease outbreaks represent rare events that are difficult to quantify (Flint et al., 2005; McMeekin et al., 2006). The case for maintaining water quality MPs, while compelling, also contains ambiguities. Scientists have only recently begun collecting data needed to evaluate the effectiveness of MPs in improving regional water quality (RWQCB, 2004). Although competing risk is an established subdiscipline within the fields of law (Graham and Weiner, 1997) and statistics (Pintilie, 2006), there is no scientific framework available for weighing and balancing water quality and food safety threats. More quantitative, or better developed qualitative, information will be needed to evaluate and compare competing risks. HACCP can serve as a starting point, but not a template, for developing such a system, since it will need to be restructured to consider threat mitigation rather than effective control. Regardless, forums for considering the needs and constraints of both water quality and food safety will be required to resolve present and future conflicts as they occur regionally, nationally, and internationally.

Two-year old Kyle Allgood, of Chubbuck, Idaho, died during the 2006 outbreak. His mother had added the infected spinach to his smoothie to improve its nutrition (Davey, 2006). Water and sediments leaving area farms are carrying pesticides and nutrients. These pollutants cause widespread damage to fauna and their community structures in local rivers and estuaries (Anderson et al., 2006). The current crisis calls for both food safety and water quality professionals to create together a competing risks subdiscipline that applies science and design principles toward resolving conflicts between human and environmental health.

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