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Introduction to the Symposium on American Food Resilience

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Introduction to the Symposium on American Food Resilience

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Abstract The resilience of the American food supply—the ability of the food system to withstand shocks or stresses that could lead to disruption or collapse—is a matter of genuine concern. While all seems well with supermarkets stocked to the brim, changes in the food system and our environment during recent decades have created risks that are no longer hypothetical possibilities. They are with us now. The 27 articles in the Symposium on American Food Resilience explore the vulnerability and resilience of food production and distribution from a diversity of perspectives. Four central questions provide a framework for the exploration:

- What are the main lines of vulnerability?
- What are leverage points for reducing the risks and improving the capacity to deal with breakdowns if they occur?
- What is already being done by government, civil society, and the private sector to reduce the risks?
- What can scientists, teachers, and other environmental and food system professionals do through research, education, community action, or other means to make the food system and food supply more resilient?

Some of the articles use case studies that highlight various kinds of disturbances: influenza pandemic, war, nuclear reactor catastrophe, natural disasters (e.g., floods and earthquakes), and crop failure due to drought or other climatic perturbations. Lessons for improving resilience are drawn from the experiences. Other articles examine the significance of globalization, food system consolidation, diversity, and food storage; the interplay of efficiency, adaptive capacity, sustainability, and resilience; the potential and limitations of local or regional food systems to compensate for shortcomings in the mainstream food system; organizational learning and networking, integrating local food systems with the mainstream, channeling promising innovations into the mainstream; and success stories and the lessons they offer. The articles afford a wealth of material that can be mined by researchers, teachers, practitioners, and policy makers for application to their own circumstances.

Keywords: Food system, Food security, Food crisis, Food supply, Food supply chains, USA, Resilience, Sustainability

Introduction

Americans take their food supply for granted, counting on grocery stores well-stocked with a wide variety of foods as a way of life. Cost of food as a percentage of income is among the lowest in the world (Pinstrup-Andersen and Watson 2011; Thompson 2013). Production and distribution have been

impressively reliable. However, our food supply may not be as secure as it seems (Endres and Endres 2009; Ladner 2011). Difficult-to-predict disturbances such as energy crisis, severe drought in a major food-producing region, or prolonged influenza pandemic could disrupt food production or distribution severely enough to set a breakdown in motion. The risk of serious shortfall in food supply, whether on a local scale or larger scale, or shorter or longer period, is of genuine concern. Cities are particularly dependent and vulnerable. It is difficult to get a clear grip on this issue because the food system is so complex (Fig. 1) and failure could take forms never seen before. It is easy for wishful thinking to prevail, but the stakes are high.

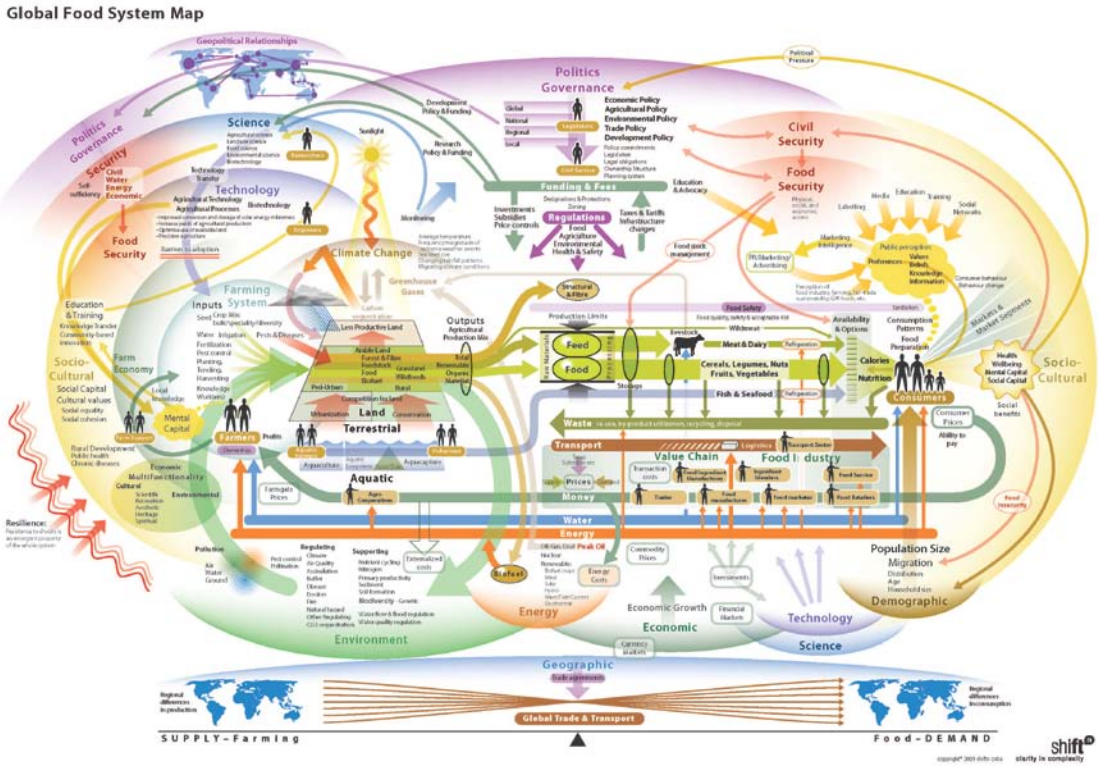

Figure 1. The food system with its numerous flows and cause-and-effect relationships. Source: shiftN (http://shiftn.com). Flows along food supply chains (Bourlakis and Weightman 2004; Burch and Lawrence 2007; Pullman and Wu 2012), from farms to processing and packaging, distribution, retailers, and consumers are shown as "value chain" in the diagram.

In 2013, an informal working group was formed in the Association for Environmental Studies and Sciences (AESS) to explore the resilience of the American food supply: *the ability of the food system to withstand shocks or stresses that could lead to disruption of the food supply*. The following questions provided a framework for exploration:

- What are the main lines of vulnerability in the American food system?
- What are leverage points for reducing the risks and improving the capacity to deal with breakdowns if they occur?
- What is already being done by government, civil society, and the private sector to reduce the risks?

- What can scientists, teachers, and other environmental and food-system professionals do through research, education, community action, or other means to make the food system and food supply more resilient?

Much of the published literature on "food security" concerns the significance of the contemporary globalized food system for less-developed countries, "world hunger," and the challenge of feeding a larger human population in the future (Ingram et al. 2010; Ringler et al. 2010; McDonald 2011; Conway 2012; Gibson 2012; Patel 2012; Peacock 2012; Gardner 2013; McMichael 2013; Rosen et al. 2013; Naylor 2014). The existing literature on food security in the USA focuses on "food justice," access to nutritious food, and local food movements as a means to compensate for shortcomings in the mainstream food system (Winne 2008; Alkon and Agyeman 2011; Ladner 2011; Cockrall-King 2012; Kneafsey et al. 2013; Ackerman-Leist 2013; Gottlieb and Anupama 2013;Wilde 2013; Neff 2014). While social justice and access to food are an important part of resilience in food supply, they are not the central focus for the questions listed above. Food supply resilience is about the risk of breakdown in the food supply itself and what can be done about it—an aspect of the food system that has received relatively little attention in the published literature.

A series of presentations at the 2013 AESS annual conference was a first step in addressing the questions listed above. (See Marten 2013 for a complete record of the presentations and discussions: http://ecotippingpoints.org/resources/presentation-food-resilience/presentations-food-resilience.pdf) While together at the conference, the presenters proposed assembling a collection of articles for the *Journal of Environmental Studies and Sciences* to address these questions. The purpose was to frame the American food resilience issue for the Journal's broad readership in a way that would throw light on the food system from a variety of angles that connect to the resilience of the food supply. The result is this Symposium on American Food Resilience. A list of the articles and their abstracts can be seen in the appendix.

Some key elements of the problem

Vulnerability in Hawaii[1]

I live on the island of Oahu, which imports approximately 90% of its food, almost all of it coming by boat from the US mainland. I first became concerned about food resilience when I contemplated what might happen to Hawaii's food supply after a severe hurricane or during a prolonged influenza pandemic. Though I was unable to find anyone at any level of government responsible for what would happen to the food supply in Hawaii during an influenza pandemic, I was able to talk with the Hawaii State Civil Defense staff responsible for hurricane preparedness. They were forthright and helpful, but what I learned was unsettling. The prospects for feeding Oahu's million inhabitants during a crisis such as the aftermath of a direct hit by a severe hurricane are far from encouraging. With the harbor and airports potentially out of action for weeks and electrical power down for even longer, the island's usual channels for food supply could be crippled for a month or more. Civil Defense disaster planners estimate that the food stock at grocery stores and their warehouses is enough for about 5 days, though less could be expected to survive a hurricane because commercial food storage facilities are located close to the ocean where they will be exposed to damage from storm surge. Add to that the food at home in kitchen cupboards after losing refrigerated food due to lack of electricity, and you have an idea of what will be available if the food supply to the island is cut off.

[1] First person accounts regarding Hawaii and New Orleans are from the lead author (Marten).

What can we expect from the federal government? The Federal Emergency Management Agency (FEMA) has a warehouse on Oahu with 30,000 MREs (Meals Ready to Eat), enough for a single meal for 3% of the island's population. This mismatch between FEMA's storage and actual needs highlights the challenge of feeding so many people on short notice by any means other than the existing food supply system. We could expect the military, in coordination with FEMA and the state, to bring some food to Hawaii, but government has its limitations. We only need to recall the thousands of people stranded in the New Orleans Superdome after Katrina to realize that we cannot always depend on government in times of severe shock and crisis. I was told that the state and local governments are responsible for transporting food from wherever it is locally available (e.g., harbor or airport) to food distribution points such as disaster shelters or retail outlets if conventional local transport breaks down. However, existing commercial channels are expected to bear the responsibility for almost all food transport from the US mainland to Hawaii during a crisis, no matter what the cause and whether the crisis is shorter or longer in duration.

Of course this alarming vulnerability is not unique to Hawaii. The supply of locally stored food in the nation's rapid-turnover "just in time delivery" economy and refrigerator-based households is typically no greater than in Hawaii. Every American city is an "island," dependent for its food on a continuous stream of trucks or other transport. While food assistance for a short-term crisis in a single area of continental USA can come from other areas, assistance may not be forthcoming during a crisis that impacts the entire nation or a large region at the same time.

Crisis in Britain

The British "fuel protest" in September 2000 demonstrated how quickly a relatively small event can trigger a nationwide food crisis. The trouble began when truckers responded to a sudden increase in the price of diesel fuel by blockading fuel delivery to petrol stations (PSEPC 2005; McKinnon 2006). It was not a strike. Instead, the truckers used their vehicles to block the roads coming out of oil refineries and fuel distribution centers. Within 2 days, about half of the nation's petrol stations ran out of fuel, and grocery stores were out of milk, eggs, bread, fruits, and vegetables. Panic buying of the remaining food in stores quickly followed. The protest ended after 6 days, when the government agreed to form a commission to examine fuel price. By that time, the shelves of most grocery stores were empty, many people were unable to travel to work, and much of the manufacturing sector was on the verge of shutting down. It took about 2 weeks to return to normal. While there was no starvation, the food supply was headed for collapse, and the society in general headed for chaos, if the blockade had lasted for even a few more days. Soon after the crisis, the government forged an emergency response plan in which police would immediately break up blockades in order to ensure fuel deliveries if this should ever happen again.

Insights from New Orleans

How does it come about that we can be so vulnerable? The basic process underlying vulnerability and resilience is illustrated by the experience of New Orleans with Hurricane Katrina, where in August 2005, flooding transformed nearly half the city into a ghost town in a single day. I lived in New Orleans East (http://nolaeast.com). For miles around my former home, there was no water or electricity for years after the flood. While much of New Orleans is now doing well, recovery in that suburban part of the city has proceeded slowly and is still far from complete. Vacant lots and empty houses remain a conspicuous part of the landscape, and there are few large commercial establishments such as shopping malls or

grocery stores (Jervis 2011). Astonishingly, right up until Katrina, the prospect of such a devastating flood was not on the radar of most politicians or the public at large. How could they be so mistaken about the risks? What went wrong?

The collapse, though sudden, was a consequence of a gradual and inconspicuous increase in vulnerability over half a century. Before Katrina, people in New Orleans did not expect such devastating long-term consequences from a hurricane because the city had previously recovered from every hurricane that came its way. Until the mid-twentieth century, the city was built almost entirely on high ground. In areas at risk of flooding, the houses were built high above the ground so flood water would pass underneath, and they were built of wood that would dry quickly after a flood. Miles of marshland between New Orleans and the ocean protected the city from storm surges.

All of this changed during the last half of the twentieth century, as a false sense of security from flood-control levees encouraged suburban growth into low-lying, floodable areas. At the same time, the traditional flood-resistant house design was forgotten. Houses in the new subdivisions were built right on the ground with standard American double-wall construction, which in the New Orleans climate becomes a mold-infested tear down when a house is flooded. On top of that, the levees were gradually deteriorating, no longer providing the protection that virtually everyone assumed was there. And the marshland that protected the city from storm surges was gradually wasting away, inconspicuously losing a football field of marshland every 15 min, decade after decade, because the levees blocked the flooding and sediment deposition that had maintained the marshes in the past (Marten 2001). By the time all these changes piled up, there was no question whether New Orleans would succumb to devastating flood damage during a direct hit by a hurricane; it was only a matter of when the “trigger”—the hurricane—would come along to make it happen. A telling lesson on the significance of culture was provided by the fact that the Vietnamese community in New Orleans East, which immediately started repairing their homes and commercial establishments in the flooded area, was functioning more or less normally within 8 months after the flood (Chiang 2009).

The New Orleans experience offers clear implications for the American food system. Breakdown is a consequence of vulnerability plus disturbances that play on the vulnerability to trigger the breakdown. Increases in vulnerability, increases in the frequency or intensity of disturbances, ignoring warning signs of vulnerability, and shortcomings in the ability to adapt and recover from damage all increase the risk (Walker and Salt 2012).

Sources of vulnerability

The list of vulnerabilities and disturbances that could plausibly trigger disruption or collapse in food supply is a long one. The following are some examples:

The diminishing gap between global food production capacity and the food needs of a growing human population The ability to meet food needs when things go wrong is greater when food production capacity comfortably exceeds food needs. While global food production is now greater than ever (Fraser 2015), the agricultural potential of the planet is eroding as farmland is lost to urban expansion, erosion, salinization, and other abuses (Cribb 2011; Brown 2012; Foley 2014). Aquifers that provide irrigation water on which so much of the increase in agricultural production during recent years has depended are rapidly being depleted. More food is being produced now at the expense of food production in the future. At the same time, the demand for food is increasing due to a growing human population. The

pressure on land, water, and other food-producing resources is compounded by the increase in demand for animal products as people around the world acquire Western dietary habits.

Food system complexity The existing food system is a product of many years of intensive economic competition in a free market economy, shaped by more than a century of government policies in support of that system and shaped in recent years by sophisticated information processing enabled by computers. While the unprecedented scale and efficiency of today's food system have been successful at meeting expanding consumer demands, the impressive achievements may have been at the expense of resilience. Food supply chain enterprises respond to the demands of consumers who, because of the system's complexity, know little about where their food comes from or distant environmental and social consequences of their food choices (Dyball and Newell 2015). Furthermore, strengths that have made the food system stable have also sheltered the system from "exercising" and maintaining its capacity to deal with disturbances. The complexity that makes everything run so smoothly can be inflexible or unwieldy in the face of exceptional shocks or stresses (Tainter 1988, Marten 2001; Gardner 2013; Rosen et al. 2013). For example:

- Efficiency can be in conflict with resilience (Goerner et al. 2009). Redundancy contributes to resilience because it provides backup for when things go wrong, but redundancy is often not efficient. "Just in time delivery," whose efficiency is essential for economic survival in today's competitive world, along with government economizing by closing down food storage depots, has virtually eliminated the food storage that cushioned disruptions in food supply during earlier times. Global food storage is now down to enough food for about 2 months (Brown 2012), and the storage in many parts of the American food system is much less.
- A common "emergent property" of complex bureaucratic systems in public and private sectors is "taking on a life of their own" in ways that are contrary to their mission (Allison and Zelikow 1999). Agriculture in California's Central Valley, which has accounted for approximately 30%of the nation's fruit and vegetable production in recent years, is a paragon of high-tech sophistication and economic efficiency. However, the political institutions responsible for accommodating conflicting stakeholders have failed to deal with the realities of the region's water supply, precipitating a crisis that has crippled agricultural production during 2014–2015 and threatens to continue doing so in the future (Keppen and Dutcher 2015).

Disease pandemic Severe influenza pandemic is one of the most likely scenarios for serious disruption of food supply. Experience with previous pandemics suggests that there would likely be a series of surges in the illness, each surge lasting for several months and creating as much as 25–40 % worker absenteeism (FFIEC 2007). The total duration of a pandemic could be more than a year. Absenteeism would be high not only because people are sick but also because people stay home to care for sick family members or simply because people stay away from work to avoid infection. A workforce shortage would not only impact all stages of food supply chains directly; workforce shortage would also impact the supply of fuel for operating transport vehicles and farm machinery, as well as electricity generation on which food processing plants, storage facilities, and retail outlets depend (Kelley and Osterholm 2008). While there are very few quantitative studies on the impact of workforce shortages on food supply, a simulation study of milk supply concluded that a 25% reduction in workforce during infection surges of several months could reduce the milk supply by 50 % during those periods (NISAC 2007). The consequences of an overall food supply reduction of that magnitude would be devastating if it really happened.

Crop failure due to extreme weather While drought and floods have been responsible for failed harvests for as long as there has been agriculture, global climate change is amplifying the frequency and severity of extreme weather. The 2011 Texas drought, which forced emergency reductions in cattle stocks, and the 2012 Midwest drought, which damaged corn and soybean production, were wake-up calls (Lengnick 2015a). California's water crisis has sent a clear message that this kind of disaster is not to be discounted as something that could hypothetically happen in the future. It is with us now. Irrigation water shortfalls will become more frequent across the nation and around the world as snowpacks decline, agricultural demands for water increase, and aquifers are drawn down (Ringler et al. 2010).

Greenhouse gases are not the only source of damaging weather. Sunspots are implicated as responsible for the Little Ice Age (1300–1850), when Europe experienced dozens of periods characterized by several years of excessive spring rains, cold rainy summers, a drastically shortened growing season, crop failure, and widespread hunger or downright famine (Fagan 2001; Smith 2012). Famine was often followed by disease that claimed even more lives than the starvation. The "Great Famine" (1315–1321) killed approximately half the population of northern Europe and led Europe's weakened population into the Black Death a few years later. Periodic volcanic eruptions that cast massive quantities of sulfur dioxide into the atmosphere created the same kind of debilitating weather when sulfur dioxide aerosol from the eruptions spread to far corners of the globe, concentrating in distant regions where it reflected sunlight and created as much as 3 years of unprecedented dark skies, shortened growing seasons, and hunger (Perkins 2008; Oppenheimer 2011). In tropical regions, dark skies from volcanic eruptions disrupted tropical monsoons, creating drought and famine in areas such as India and China (Witze and Kanipe 2014). During the "Year without a Summer," actually 2 years (1815–1816), volcanic eruption from Mt. Tambora (Indonesia) not only burdened western Europe with cold and hunger; it was also responsible for crop failure along North America's eastern seaboard severe enough to precipitate a mass migration of farmers from New England to the Midwest (Wood 2014).

During the past 150 years, the planet has enjoyed an exceptionally warm, benign climate, in part because of greenhouse gases. Agriculture has flourished, and recent advances in agricultural technology have covered the planet with crop varieties that take full advantage of each region's growing season to produce the highest possible yields. However, those crop varieties may also be seriously vulnerable to failure if the growing season is suddenly much shorter. The kind of crisis that could arise after severe volcanic eruption or other sudden climatic shift may seem too remote to be a compelling concern, but it can be expected sooner or later. We can ask how well we will fare.

Failure in the supply of inputs for food production, processing, and distribution A breakdown in energy supply could have far-reaching effects (Gunther 2001). The fossil fuel energy now employed for fertilizer production, farm machinery, food-processing factories, refrigeration, and transport far exceeds the energy content of the food. We are "eating petroleum" (Pfeiffer 2006). While depletion of fossil fuels will be gradual, energy price fluctuations can be sudden, putting essential farm inputs beyond the reach of farming systems that are completely dependent upon them. The supply of material inputs for agriculture could also be at risk; for example, phosphorus fertilizer. While Morocco may have enough phosphorus reserves (though largely unproven) to supply the entire world for centuries, phosphorus reserves elsewhere (and known to be extractable by current methods) are headed for depletion within decades (Vaccari 2009), possibly leaving worldwide agriculture vulnerably dependent on a single source of phosphorus.

Loss of seed diversity is another concern. A small number of "industrial" crop varieties produced by hybridization or genetic modification now dominate large regions, rendering them vulnerable to resistant pests or diseases and dependent on the few corporations that provide the seed (Qualset and Shands 2005; Fuglie et al. 2011; Heinemann et al. 2013). International trade and transport can move deadly crop pests and diseases quickly around the planet, and the same is true for livestock, as evidenced by the massive slaughters necessary after outbreaks of hoof-and-mouth disease and mad cow disease in Britain and the current outbreak of bird flu in the USA (Chalk 2004). Particularly alarming is the business model of corporations providing genetically modified seeds that must be purchased anew every year. India has shown what can happen. After India converted almost entirely to Bt-cotton for protection from insect pests, shortages in the Bt-cotton seed supply since 2011 have led to widespread financial ruin among farmers, who have been unable to return to their previous cotton varieties because those seeds have virtually disappeared (Swagerty 2014).

Societal breakdown Social conflict or failure can interrupt labor, damage physical or social infrastructure, and in extreme instances lead to a general societal breakdown and collapse of the food supply. Disrupting the food supply of adversaries has often been a major strategy in war (Maltz 2015). The worst famines in history have in fact occurred during relatively recent times as a consequence of war, imperialism, or despotic government (O'Grada 2010): India (1878–1879, 1942–1944), China (1877–1879, 1959–1961), and the Soviet Union (1932–1933, 1946–1947). Similar mishaps (http://en.wikipedia.org/wiki/List_of_famines), which have happened even more recently in Cambodia (1975–1979), North Korea (1995–2000), the Congo (1998–2004), and elsewhere (e.g., Somalia and South Sudan) right up to the present time, are also conceivable in the future (Cribb 2011). Although poor nations have been more vulnerable, wealthier nations may not be immune. The USA has not had war or other such sweeping calamity on its soil since the Civil War. How well would the food supply hold up if it happened?

Of immediate concern to the US government is the threat of terrorist attack that would contaminate the food supply or introduce crop or livestock disease (Chalk 2004). Moreover, conflict need not take the form of direct physical destruction. The risk of cyber attack is a relatively new but alarming concern because food processing and distribution worldwide depend so heavily on computer systems. Not only could cyber attack cripple food system operations directly; food systems could also be crippled indirectly by attack on electricity grids or fuel supply networks on which food supply chains depend (Adams 2013, Zhang 2013).

Globalization (multinational corporations and international trade and investment) The globalized food system is now controlled in large measure by a few international conglomerates that exercise enormous influence over national and international markets, trade rules, and other conditions that impact their profits (Burch and Lawrence 2007; Ingram et al. 2010; Clapp 2012; Patel 2012; Wilde 2013; Neff 2014). Because they follow business models that could potentially be in conflict with a resilient food supply, a small number of people in charge of those corporations have the power to do a lot of good or a lot of harm. American food-retailing corporations demonstrated the harm when they pulled out of poor urban neighborhoods, creating "food deserts" that make it difficult for residents to purchase nutritious food at a decent price (Winne 2008;Walker et al. 2010; Gottlieb and Anupama 2013).

While international trade can contribute positively to food resilience when nations with a food surplus provide food assistance to needy nations, international competition for food can leave some nations without the supply they need. The USA, which until now has enjoyed an abundant and secure food supply with its wealth of natural resources and economic advantage in the global marketplace, could

conceivably be on the short end as food needs and international power relations shift during the coming years. For example, China with its massive population, rapidly expanding consumption of animal products, and declining food production at home due to aquifer depletion, urban expansion over agricultural land, and farm-labor shortage could have the need and the economic power to compete seriously with Americans for food. Chinese agribusiness is increasing its control of food-producing resources around the world, purchasing million-acre chunks of agricultural land in Africa and substantial quantities of food-producing resources elsewhere, including major pork production operations and other agribusiness enterprises in North America (GRAIN 2012; McMichael 2013). China's dramatic increase in consumption of dairy products is a welcome development for California farmers who look forward to expanding their dairy exports, but dairy production requires large quantities of water in a state where the water used for crops, growing cities, fracking, and maintenance of natural systems already exceeds the supply (Keppen and Dutcher 2015).

Anatomy of an international food crisis

The 2008 global food crisis demonstrated how relatively small and often localized shocks can spread and amplify through the system (Lagi et al. 2011; Clapp 2012). International wheat, rice, corn, and soy prices doubled in less than a year. How did this happen?

The initial shock was a concurrence of (1) poor harvest in Australia due to drought and (2) diversion of American grains to biofuel production (Fig. 2). Some of the key grain-exporting nations responded by restricting their exports in order to protect their domestic food supplies from an anticipated increase in international food commodity prices. The subsequent drop in the supply of food commodities in international markets drove up international food prices, creating a vicious cycle that caused food-exporting nations to further restrict exports and international prices to increase even more. This price increase was exacerbated by a low "stock-flow ratio" (i.e., insufficient wholesale food storage to buffer the reduction in food supply) and reinforced by an increase in the price of petroleum, which added to on-farm, processing, and transport costs and ultimately the cost of food.

On top of that, the subprime mortgage crisis, and the recession that followed, reduced international credit and the ability of nations with food shortages to buy food from abroad. Then, commodity futures trading came into the picture. The recession led to a decline in the US dollar, which led investors to shift from conventional investments (e.g., stocks) to commodities (including food commodities), stimulating higher food prices and a spiral of speculative investment in deregulated food commodity futures markets, driving food prices even higher. The result was food riots in dozens of nations. At the same time that direct consumers of grains were suffering, prices for the great variety of processed foods in American grocery stores were virtually unaffected because markups along American food supply chains are so large that the price of wheat, rice, corn, and soy inputs is of little consequence for the price of the final products. However, more severe price perturbations in the future could cross a threshold leading to significant impacts even here.

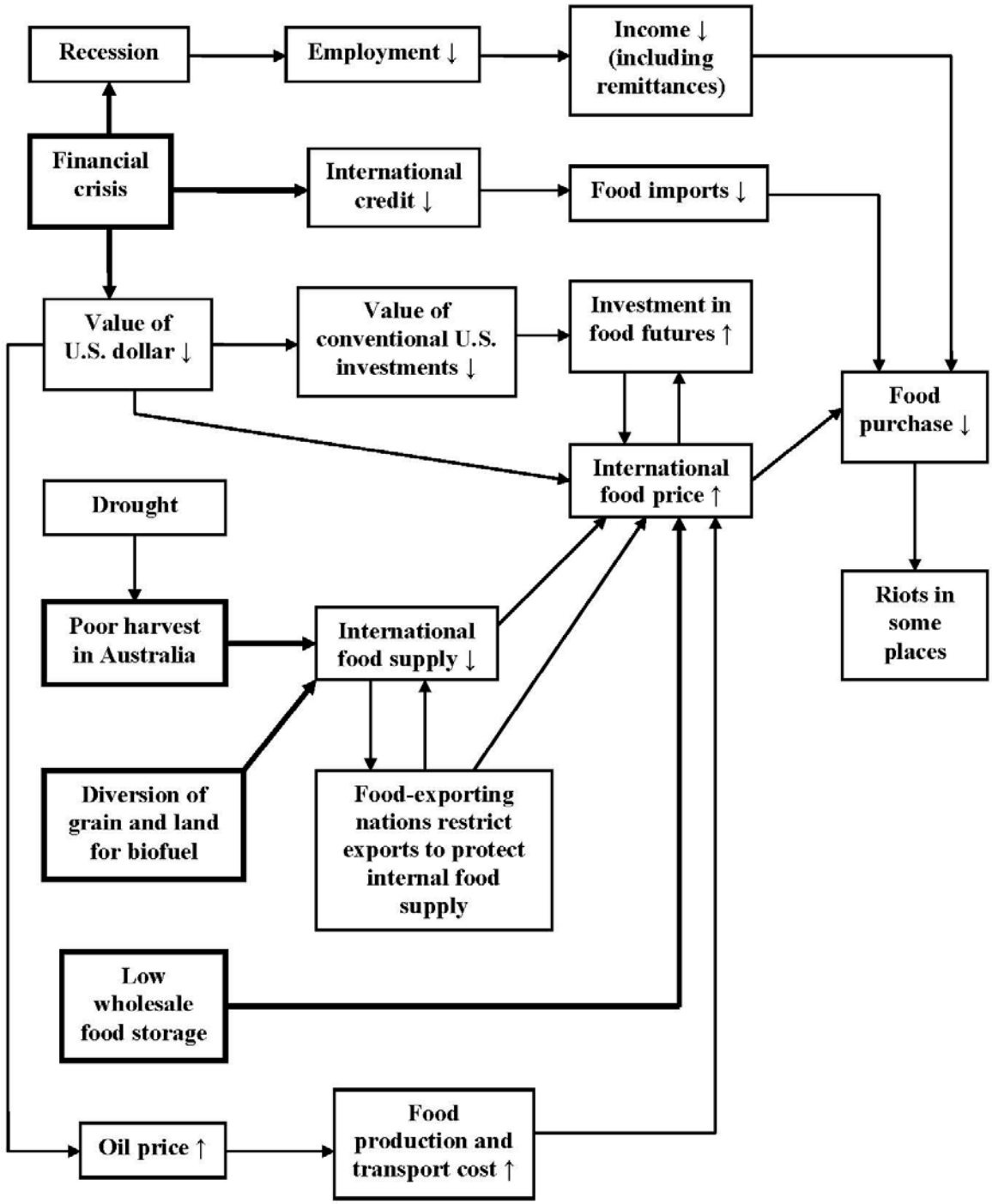

Figure 2. Increase in international food commodity prices triggered by poor harvest in Australia and diversion of grain to biofuel and exacerbated by the financial crisis, an increase in the oil price, and low wholesale food storage. Arrows inside the boxes show the direction of changes (increase or decrease) that resulted. Based on a narrative of the 2008 food crisis in Clapp (2012)

The Symposium on American Food Resilience

The articles in this symposium address the four questions at the beginning of this introduction: sources of vulnerability, leverage points for reducing risks, what is already being done, and what environmental and food system professionals can do to make the food supply more resilient. Each article explores a particular aspect of the food system, connecting it to resilience in a way that the authors and others in their field may not have done before. The significance of each article resides not only in what it contributes on its own but also in its contribution to the symposium as a whole. Taken together, the articles aim to contribute to a comprehensive framing of American food resilience that will facilitate its development as a serious object of both research and action.

Most of the articles do not follow a conventional or narrowly focused research format. They tend to be broad and exploratory. Some contain several thrusts instead of a single theme. Authors range from academics to a journalist and representatives from nonprofit organizations. Stakeholder perspectives are a legitimate part of the mix. Some of the articles focus on theory, others employ quantitative techniques, and many are descriptive or based on narrative. Sources of information range from the usual academic venues to newspaper articles, personal experience, and anecdotal information. While the bottom line for this symposium is food supply for the USA, some of the articles contribute insights by recounting experiences in other countries such as Australia, Germany, Ukraine, Japan, and Canada.

This symposium is in two parts. While all the articles address both problems and solutions, part 1, which is in this issue, sets the scene by touching on various aspects of the food system and highlighting vulnerabilities (Table 1). Some of the articles in part 1 use political-economic analysis (Jacques 2015), resilience theory (Hodbod and Eakin 2015), or system dynamics modeling (Stave and Kopainsky 2015) to explore vulnerability and resilience from a theoretical perspective. Other articles describe prominent changes in the food system during recent decades—such as consolidation of food supply chains (Rotz and Fraser 2015; Hendrickson 2015) and the decline of food storage (Fraser et al. 2015)—and the implications of those changes for resilience. Still, other articles recount actual experiences and lessons learned when shocks such as drought (Keppen and Dutcher 2015; Lengnick 2015b), flooding (MacMahon et al. 2015), nuclear-reactor disaster (Belyakov 2015), or war (Maltz 2015) have disrupted food production or delivery. Other articles in part 1 look at simulated experiences such as the impact of an influenza pandemic on food supply (Huff et al. 2015).

Table 1. Overview of articles in the Symposium on American Food Resilience (Part 1) (Abstracts may be seen in the appendix.)

Stave and Kopainsky (2015) doi:10.1007/s13412-015-0289-x	Explains how system dynamics can help conceptualize the mechanisms and pathways by which food systems can be affected by disturbances. The process of creating stock-and-flow and causal-loop diagrams, and the visual representations in the resulting diagrams, can assist stakeholders to see connections between organizational, environmental, and food issues.
Huff et al. (2015) doi:10.1007/s13412-015-0275-3	Uses a simulation model to demonstrate the likely effects of a severe influenza pandemic and reduction in the workforce on food supply. A pandemic with greater than 25% reduction in labor availability can cause serious and possibly devastating food

	shortages.
Lengnick (2015b) doi:10.1007/s13412-015-0290-4	Summarizes climate changes and effects on agriculture to be expected in different regions of the USA and examines the capacity of the food system to adapt to climate change. Agricultural specialization and concentration in different geographic regions increase vulnerability to climate change.
Keppen and Dutcher (2015) doi:10.1007/s13412-015-0283-3	Describes the water crisis and irrigation water allocation to farmers in California's Central Valley as a consequence of environmental laws and regulations. Recommends mediated settlement among conflicting stakeholders and an increase in water storage infrastructure to improve the reliability of the water supply.
MacMahon et al. (2015) doi:10.1007/s13412-015-0278-0	Describes the impact of a severe flood in Queensland, Australia, on food delivery to supermarkets, comparing the strengths and weaknesses of long and short supply chains in the aftermath of the flood. Recommends better government coordination of all stakeholders, including not only major retail chains but also local farmers and civil society, in future crises.
Maltz (2015) doi:10.1007/s13412-015-0293-1	Compares the food production and supply strategies of the USA, Great Britain, and Germany during the two world wars to explain why Germany's food supply collapsed during World War I but the USA and UK did not. Experiences from the wars offer lessons on how to reconstruct food systems when they are disrupted.
Belyakov (2015) doi:10.1007/s13412-015-0284-2	Compares government disaster management and public communications after the Chernobyl and Fukushima nuclear reactor accidents. Misinformation and incomplete information can bias decision-making and political actions. Clarity and consistency in communication about the safety of food supplies, and attention to social justice issues, should be an integral part of government response to such disasters.
Hendrickson (2015) doi:10.1007/s13412-015-0292-2	Examines the risks of a consolidated, industrialized agri-food system for the environment and the ability to guarantee a reliable food supply. Key challenges for sustainability and resilience of the agri-food system are a consequence of power relationships in the capitalist system.
Jacques (2015) doi:10.1007/s13412-015-0294-0	Examines from a theoretical perspective the impact of food-industry power on the autonomy and problem-solving capacity of civil society. Counterrevolutionary actions by industry to maintain the neoliberal food regime undermine food system resilience.
Fraser et al. (2015) doi:10.1007/s13412-015-0276-2	Explores the role of government food storage as a component of robust food security strategy by drawing on historical evidence, reviewing links between food storage and price volatility, and contrasting three different grain reserve policies. Food storage has fallen out of favor and declined in recent years.
Rotz and Fraser (2015) doi:10.1007/s13412-015-0277-1	Discusses the impact of industrialization of the food system in the USA and Canada on system diversity, the strength of connections, and decision-making autonomy. Changes in all of these during recent years have eroded system resilience. Publicly led

	multifunctional policies can support more diversified production while programs to promote food system localization can increase autonomy.
Hodbod and Eakin (2015) doi:10.1007/s13412-015-0280-6	Discusses how the resilience of food systems is distinct from conceptualizations of resilience in social-ecological systems in general. Uses the California drought of 2013–2015 to illustrate functional and response diversity as key attributes of resilient, multifunctional food systems.

Part 2 will appear in the next issue of this journal and emphasizes what can be done to strengthen food system resilience and what is already happening in that regard (Table 2). Some of the articles in part 2 will explore ways to correct or deal with flaws in the mainstream food system, which supplies nearly all of our food, now and in the foreseeable future. Other articles will focus on local and regional food systems, their potential to compensate for shortcomings in the mainstream system, and their limitations as well. Some articles will be concerned with civil society or public policy. Part 2 will end with a concluding piece that draws upon messages from the symposium articles to enumerate key issues, probe questions that they raise, and outline key concepts and action strategies for improving American food resilience.

Table 2 Overview of articles in the Symposium on American Food Resilience (Part 2) (Abstracts may be seen in the appendix.)

Anderson (2015)	Compares knowledge generation, transmission, access, and use in four food system domains based on low or high levels of globalization and low or high levels of multi-functionality: “Global Industrial,” “Independent Commercial,” “Local & Sustainable,” and “Fair Trade.” Using the Committee on World Food Security as a case study, it demonstrates how knowledge generation, transmission, and access must be participatory, multi-actor, iterative, and transparent to build food security.
Candy et al. (2015)	Uses scenario-based simulation modeling with the Australian Stocks and Flows Framework to explore the significance of alternative agricultural policies for resilience of the Australian food system in the face of future stresses. Applying the model to the food supply of Victoria state, it examines land use, crop production, livestock production, fisheries, food processing, transport, and food waste.
Lengnick et al. (2015)	Proposes strong (nationally linked) metropolitan area food systems to deal with the challenge of climate change and weaknesses due to existing geographic specialization and concentration. Metropolitan food systems should be based on regenerative ecological design and adaptive management to promote the diversity, modularity, tight feedbacks, and balance of natural, social, built, and financial capital required to enhance sustainability and resilience.
Dyball (2015)	Compares the food production and supply strategies of the Canberra, Copenhagen, and Tokyo metropolitan areas to show how cities can be vulnerable. Proposes shift to a “biosensitive” paradigm to overcome alienation of urban communities from the realities of

	their food supply. Local food literacy and involvement can create politically engaged and biosensitive citizens to build resilience.
Hoy (2015)	Examines relationships between stability, sustainability, equitability, productivity, autonomy, and agroecosystem health with examples from the Agroecosystems Management Program at Ohio State University. Adaptive management experiments with self-organizing social and economic networks supporting agroecosystem diversity and health can help to strengthen the resilience of food production and distribution.
Ward (2015)	Uses linear programming optimization to assess how much urban agriculture can contribute to food self-sufficiency, subject to limitations of land and water. A linear programming study of food production and consumption in Adelaide, Australia, indicates that home food production could cover 10–15% of protein consumption and reduce grocery costs by 10–20%, depending on the quantity of meat in the diet.
Atalan-Helicke (2015)	Examines risks and vulnerabilities in seed systems and describes seed exchange networks in the USA, including civil society and private initiatives. Formalization of such initiatives to maintain, improve, and create open-pollinated varieties of cereals and vegetables for farmers and gardeners is crucial for building resilience in the food system.
Paci-Green and Berardi (2015)	Explores how an earthquake and tsunami that severely damage harbors and roads in Washington state would impact the food supply. Regional food production could contribute substantially to food consumption during an emergency if there is sufficient regional food storage.
MacFall et al. (2015)	Examines how regional diversity in food production and distribution can strengthen resilience. Diverse cropping systems such as “biointensive cultivation” increase water-use efficiency, yield, and nutrient retention while reducing damage from pests and pathogens. A diverse system of food production, processing, and distribution in the North Carolina Piedmont and a food hub in South Carolina illustrate improved access of consumers and producers to local markets, contributing to a resilient regional system.
Ruhf (2015)	Discusses how strengthening regional food systems contributes to resilience. New England provides a case study highlighting the region as an effective scale for collaborative initiatives by government, nonprofit organizations, and the private sector to promote resilience on a variety of fronts through enhanced diversity, flexibility, appropriately scaled supply chains and infrastructure, and strong institutional relationships.
Tolley et al. (2015)	Reviews the history of federal government management of New England groundfish, which have suffered recurrent stock collapse during the past 50 years. Privatized “catch shares” currently threaten the fishery with takeover by large-scale industrialized fishing boats and unsustainable fishing. Small- and medium-scale

	fishermen with longstanding roots in the region have organized a Fish Locally Collaborative with "community-supported fisheries" to undertake marketing initiatives and other actions aimed at restoring health and viability to local fishing communities and the fishery.
Miller and Solin (2015)	Shows how storytelling can be combined with systems thinking and civic engagement to build resilience in the food system. Using this approach, collaboration of teachers and scientists with farmers can contribute to development of adaptive strategies that enhance sustainability and resilience.
Dunning et al. (2015)	Examines how existing supply and distribution systems of supermarket retailers create vulnerabilities in the food system. Partnership of the Center for Environmental Farming Systems with a retail chain in North Carolina enabled the development of diversified procurement and distribution, integrating local farmers with the mainstream food system and enhancing regional resilience.
Marten and Atalan-Helicke (2015)	Reviews major themes and article contents in the Symposium on American Food Resilience (Part 2)

Significant themes

A number of themes resonate through the articles. One is about *change*:

- In what ways has vulnerability increased most dramatically in recent decades?
- Why has it happened?
- Can we expect vulnerability to increase even more in the future?
- What are the implications with regard to interventions that could reverse the undesirable trends and improve resilience?

Sustainability is another common theme because sustainability and resilience are closely connected (Marten 1988). Unsustainable systems are more vulnerable to shocks and stresses, and they are less equipped to recover when damaged. Sustainability and resilience are not about keeping everything the same. At times, some things must be changed dramatically in order to keep the most important things, such as a secure food supply, within acceptable bounds. The articles in this symposium offer numerous variations on the interplay of sustainability, efficiency, adaptability, and resilience—worth watching to glean insights for strategic thinking. One thing worth noting is that while resilience of the food supply is generally associated positively with the resilience of the food system as a whole, because a more functional and adaptable food system has the depth to deal more effectively with a broad range of challenges, food system resilience and food supply resilience are not identical. A food system that is dysfunctional in some ways, including weaknesses involving reliability of the food supply, may be highly resistant (i.e., "resilient") to efforts to improve it.

Some of the articles throw a spotlight on the connection between *diversity* and resilience. Basically, the value of diversity resides in not putting all of one's eggs in the same basket. Diversity provides more choices, and more choices mean more possibilities for good choices. However, it is not quite that simple.

More diversity can be associated with more complexity, which can provide more opportunities for a shock to disrupt some part of the food system in a way that spreads through the rest of the system. Moreover, it is important to recognize that diversity is multidimensional, and so is resilience. Relationships between diversity and resilience can depend upon which dimensions of diversity and which dimensions of resilience are involved, as well as details of the setting.

Another recurring theme is *scale*. The *time scale* of disturbances can vary from "shock" to "stress;" and the timing of food system responses can be equally variable. The articles in this symposium illustrate what can happen over a spectrum of time scales for disturbance, response to disturbance, and response to corrective intervention. *Spatial scale* can also vary, from local and regional to national and global, with interplay among the scales. A major challenge is how to channel far-reaching and game-changing innovation and alternatives, which we often associate with local initiatives, into the mainstream food system, which may seem overwhelmingly vast and beyond our control.

Social justice is another theme. Although the focus of this symposium is on overall food supply rather than consumer access to food—i.e., the size of the pie and its reliability rather than how the pie is divided—the fact that access to food is not the same for everyone cannot be ignored. We can expect some people to be impacted more severely than others during a food crisis. The significance of this fact extends far beyond fairness. Shortfalls in food consumption by the economically less-privileged can serve as "canaries in a coal mine" for what could happen to many others during more extreme crisis.

Finally is the challenge of *leveraging improvement* (http://ecotippingpoints.org). The contemporary food system is locked into its present configuration by powerful system forces that render it resistant to many kinds of change. When attempting to improve resilience by means of interventions involving farming systems, food supply chains, food storage, integration across food system scales, disaster preparation, or any of numerous other possibilities, to be successful the interventions must be sufficiently powerful, far-reaching, and compatible with the existing system to overcome the forces that resist them (Marten 2005; Marten et al. 2005). The articles in this symposium offer a wealth of insightful concepts, suggestions for improvement, and concrete examples of successful action that can be mined by researchers, teachers, practitioners, and policy makers for application to their own circumstances.

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Appendix: Abstracts of articles in the Symposium on American Food Resilience

Editor: Gerald Marten
Coeditor: Nurcan Atalan-Helicke

Part 1 (Journal of Environmental Studies and Sciences, Volume 5, Issue 3)

Gerald Marten (EcoTipping Points Project), Nurcan Atalan-Helicke (Skidmore College)
Introduction to the Symposium on American Food Resilience
The resilience of the American food supply – the ability of the food system to withstand shocks or stresses that could lead to disruption or collapse – is a matter of genuine concern. While all seems well with supermarkets stocked to the brim, changes in the food system and our environment during recent decades have created risks that are no longer hypothetical possibilities. They are with us now. The 27 articles in the JESS symposium on American Food Resilience explore the vulnerability and resilience of food production and distribution from a diversity of perspectives. Four central questions provide a framework for the exploration:

- What are the main lines of vulnerability?
- What are leverage points for reducing the risks and improving the capacity to deal with breakdowns if they occur?
- What is already being done by government, civil society, and the private sector to reduce the risks?
- What can scientists, teachers, and other environmental and food-system professionals do through research, education, community action, or other means to make the food system and food supply more resilient?

Some of the articles use case studies that highlight various kinds of disturbances: influenza pandemic, war, nuclear-reactor catastrophe, natural disasters (e.g., floods and earthquakes), and crop failure due to drought or other climatic perturbations. Lessons for improving resilience are drawn from the experiences. Other articles examine the significance of globalization, food system consolidation, diversity, and food storage; the interplay of efficiency, adaptive capacity, sustainability, and resilience; the potential and limitations of local or regional food systems to compensate for shortcomings in the mainstream food system; organizational learning and networking, integrating local food systems with the mainstream, channeling promising innovations into the mainstream; success stories and the lessons they offer. The articles afford a wealth of material that can be mined by researchers, teachers, practitioners, and policy makers for application to their own circumstances.

Krystina Stave (University of Nevada, Las Vegas), Birgit Kopainsky (University of Bergen)
A System Dynamics Approach for Examining Mechanisms and Pathways of Food Supply Vulnerability
Understanding vulnerabilities in complex and interdependent modern food systems requires a whole-system perspective. This paper demonstrates how one systems approach, system dynamics, can help conceptualize the mechanisms and pathways by which food systems can be affected by disturbances. We describe the process of creating stock-and-flow maps and causal loop diagrams from the graphical representation of a problem and illustrate their use for making links and feedback among the human health, food, and environmental health sectors visible. These mapping tools help structure thinking about where and how particular systems might be affected by different disturbances and how flows of

material and information transmit the effects of disturbances throughout the system. The visual representations as well as the process of creating them can serve different purposes for different stakeholders: developing research questions, identifying policy leverage points, or building collaboration among people in different parts of the system. They can serve as a transition between mental models and formal simulation models, but they also stand on their own to support diagrammatic reasoning: clarifying assumptions, structuring a problem space, or identifying unexpected implications of an unplanned disturbance or an intentional policy intervention. The diagrams included here show that vulnerability of a national food system does not only or automatically result from exogenous shocks that might affect a country. Rather, vulnerability can be either intensified or reduced by the interaction of feedback loops in the food system, and buffered or amplified by the structure of stocks and flows.

Andrew Huff, Walter Beyeler, Joseph McNitt (Sandia National Laboratories); Nicholas Kelley (University of Minnesota)

How Resilient Is the United States Food System to Pandemics?

Rarely have studies focused on the second and third order effects of pandemics. Limiting the disruption of critical infrastructures during a pandemic is important for the survival and health of society (i.e., electricity, water, and food) as most medical and public health responses to a pandemic depend on these infrastructures. The studies that have looked at this issue have highlighted alarming gaps in preparedness. This study used a system dynamics model to demonstrate the likely effects of a pandemic on the United States' food system. The model reveals that a severe pandemic with greater than a 25% reduction in labor availability can create significant and widespread food shortages. The Ebola epidemic that began in 2014 has caused severe food shortages in West Africa, which are similar to the effects that this model predicts in the U.S. The likely effects of the reduction in the amount of available food are difficult to specifically predict; however, it is likely to have severe negative consequences on society. The resilience of the food system must be improved against this hazard and others.

Laura Lengnick (Appalachian Sustainable Agriculture Project)

The Vulnerability of the U.S. Food System to Climate Change

The climate change vulnerability of a food system is a function of the exposure of the system to specific climate effects, the sensitivity of the system to those effects and the capacity of the system adapt to those effects in order to maintain system integrity. A synthesis of recent literature conducted to explore the vulnerability of the United States (U.S.) food system to climate change suggests that the interaction between regional climate change effects and the geographic specialization and concentration of agricultural production in the U.S. increases the vulnerability of the U.S. food system to climate change. Vegetable and fruit production in the Pacific states are particularly sensitive to reduced water supplies, warmer winters and more variable spring weather. Grain production in the Great Plains and the Midwest are sensitive to more variable weather, warmer winters, heatwave and hot summer nights and flooding caused by more frequent heavy rains. The concentration of beef, pork and poultry production in confined animal feeding operations located in the southern Great Plains and the Southeast are particularly sensitive to increased frequency and intensity of extreme weather and interruptions in feed, water and power supplies associated with interactions between land, water and energy use that amplify climate change effects. There is evidence that climate change is already causing disruptions throughout the U.S. food system. Farmers and ranchers in the U.S. report that increased weather variability and more frequent and intense weather extremes have increased the costs and complexity of food production. Businesses operating in the U.S. agricultural supply, processing, distribution and retailing sectors are actively managing supply networks to reduce disruptions associated with climate change effects. Food systems that rely on external or distant resources and specialized production, supply and marketing chains appear to be particularly vulnerable to global environmental change. These

characteristics, widely recognized as critical challenges to the sustainability of the U.S. food system, take on new importance as barriers to climate resilience.

Daniel Keppen (Family Farm Alliance), Tricia Dutcher (Nevada Department of Wildlife)

The 2014 Drought and Water Management Policy Impacts on California's Central Valley Food Production

Water is a scarce resource in the West, creating intense competition among user groups. The problem is compounded by climate change. During 2014 and 2015, California experienced one of the worst droughts in 160 years of record keeping. The U.S. Bureau of Reclamation announced zero water allocation for Central Valley Project agricultural water service contractors—with a devastating impact on food producers. Many farmers have fallowed their fields because there was not enough water to meet their needs, and thousands of acres of citrus, almond, and other perennial crops have been ripped out. The reduction in irrigation water supply has forced farmers to draw on underground water, which is expensive and unsustainable. Water managers have to decide between supplying water for cities, agriculture, and environmental services (e.g., water flow through the San Francisco Bay-Delta). Farmers perceive the collapse of their water allocation as, in part, a “regulatory drought” brought on by political decisions about who should have the water. The growing demands of other sectors have been met at the expense of agriculture. Uncertainties in the current political process not only undermine the reliability of the agricultural water supply but also diminish the industry's ability to make long-term adaptive decisions. The implementation of environmental laws and policies has been particularly distressing to farmers because of the large quantity of water designated for environmental use and the apparent weakness of scientific evidence to justify it. The realization of supposed benefits, such as restoration of endangered fish populations, has not been convincing. Moreover, information is lacking on alternative management options that might be more effective. Two recommendations are presented as a means to increase the resilience and reliability of the water supply for all user groups: (1) a mediated settlement generated by all stakeholders involved in water use sectors that bear upon the comprehensive and long-term management of the San Francisco Bay-Delta and threatened and endangered species that depend upon it; and (2) an increase in water storage infrastructure to buffer future fluctuations in snowpack runoff.

Amy MacMahon, Kiah Smith, Geoffrey Lawrence (University of Queensland)

Connecting Resilience, Food Security and Climate Change: Lessons from Flooding in Queensland, Australia

The Australian food system is often assumed to be largely secure in the face of global environmental challenges such as climate change. In 2010/2011 serious flooding in Queensland left towns isolated, major roads and highways cut, and incurred significant loss of life and property. In terms of food security, large areas of agricultural land were inundated and food supply chains, including both long and short chains, were affected in significant ways. The impacts included increases in food prices, deterioration in food quality, reduced consumer access to food, and disruption to the sourcing, transportation, and distribution of food, grocery and other items. Examining the discourses and policies surrounding food supply during and after the floods, this paper asks, what lessons for building a more resilient food system have emerged from the 2011 floods? To explore this question, we consider policy documents, media reports, interviews and fieldwork with key stakeholders. We find evidence of strong collaboration of state government and long supply chain operators, but to the general exclusion of civil society-based community supported agriculture networks. Long chains provide the vast bulk of food to Queensland consumers, but are vulnerable when roads are cut; community supported agriculture showed resilience, but remained marginal to the food needs of most Queensland consumers. Both resilience and vulnerability were present within both long and short food supply chains. Yet, there is

limited evidence that food security issues, beyond productivity enhancement, are being considered in discussions and policies for climate change and natural disasters. We suggest that a broader view of climate change, beyond disasters and food production, has yet to be fully integrated into food security policy - and supply chain governance and practice - in Australia.

Alesia Maltz (Antioch University)

"Plant a Victory Garden: Our Food is Fighting": Lessons of Food Resilience from World War

Today the high ideals of local food production reverberate as a model of self-sufficiency and food security. In the US and Great Britain during WWI, local food production was envisioned as ammunition to win the war. To what extent have the food policies and slogans of World Wars I and II influenced current ideas of the value of local strategies of food security in maintaining resilience, and what lessons does the history of war offer about food resilience? During World War I, German and British military strategists developed plans to win the war by leveraging actions to destroy their enemy's civilian food system. This history triangulates the food resilience of a country that imported food (Great Britain) with one that grew its food locally (Germany), and one that exported surplus (the United States) to examine the strengths and limits of local food production. During World War I, Germany suffered over a million fatalities from famine, while the US and Great Britain raised their national nutritional status by the end of the war. The tragic German experience led directly to the rise of WWII, a war initiated with a "Hunger Plan." Nineteen million civilians died, many of starvation. A long historical time frame is needed to construct lessons about resilient food systems. This brief sketch of the dismantling and reconstruction of food systems in WWI and WWII draws from secondary sources to suggest novel ideas about the interplay between local production, national co-ordination, and international networks for humanitarian aid. Using the food policies of three countries—Great Britain, the United States and Germany—this history provides an opportunity to consider the characteristics of resilient food systems, and to suggest what is required to reconstruct a large-scale food system following a crisis. War, a disrupter of food systems, also provides a model of how food systems can be reconstructed.

Alex Belyakov (Ryerson University)

From Chernobyl to Fukushima: An Interdisciplinary Framework for Managing and Communicating Food Security Risks after Nuclear Plant Accidents

This comparison of government disaster management and public communications after the Chernobyl and Fukushima nuclear accidents seeks to create a framework for disaster management that enhances food resilience (the ability of food systems to withstand perturbations that could cause disruption of food supply); and in the specific case of nuclear disasters, the avoidance of contaminated food and provision of alternative foods. This paper integrates food security, emergency management, and risk communications perspectives. Misinformation and incomplete information can bias decision-making and political actions. When risk communication is inadequate, the public reacts with fear, mistrust, panic and stress. People have difficulty deciding what they can safely eat and what they should not eat. Many choose to reject all food from affected regions, which can compromise food security. Lack of proper information may lead to such extremes in behavior as avoidance of dairy products and consumption of untested foods, which may in fact have high levels of radioactivity. The measures taken by the USSR after the Chernobyl disaster lacked consistency and clarity and were not effective in providing food security for the affected people. The government also demonstrated a lack of attention to social justice in its dealings with people who moved back to the contaminated area, ignoring government policy that they should stay out. Those people still suffer from food insecurity. In Japan, food that met government safety levels was available, but many consumers nonetheless questioned the safety of food supplies and farmers often were confused about production and marketing. In both the Chernobyl and Fukushima cases, the evacuation of affected people was aimed at reducing exposure to radiation and did not

sufficiently consider psychological and physical health impacts of resettlement, nor the security and safety of food supplies. Government responses would have been more effective in some regions if a timely distribution program of adequate, safe alternative foods (especially radioprotectors) from non-affected areas had been initiated.

Mary Hendrickson (University of Missouri)

Resilience in a Concentrated and Consolidated Food System

The focus of this article is to articulate the risks of a consolidated, industrialized agrifood system for our planet's ecology and our ability to guarantee a future food supply, while also considering how the food system might become more resilient. A relatively small number of agribusiness firms, operating globally, have powerfully shaped who produces food, what is produced, how and where it's produced, and by whom it is eaten. To examine food system resilience one must see that ecological risks of agriculture (e.g. monoculture, overuse of fertilizer and chemicals, lack of genetic diversity) are intertwined with its social and economic organization; that relationships between people and between people and their particular places are critical to situate food decisions within ecology; and that issues of scale in a global food system are keenly important and challenging to resolve. Our highly concentrated global food system has resulted from horizontal and vertical integration in food system sectors and globalization of agricultural and food markets. This system constrains farmers (and others) in making choices that can fend off likely ecological and social disruptions while limiting their ability to accommodate change. It has eliminated smaller farms and businesses that provided a redundancy of role and function, resulting in few failsafe mechanisms for the food system. A focus on efficiency, standardization and specialization has decreased the diversity of scale, form and organization across the food system. Finally, the dominant food system's inability to solve food insecurity and hunger within both rich and poor countries, coupled with an industrial diet that uses up a great many natural resources, makes the system precarious. While there is no single approach at any given scale that will accomplish food system resilience, a combination of actions, strategies and policies at multiple levels that are rooted in ecology, democracy, and economic and social equality is necessary to move forward.

Peter Jacques (University of Central Florida)

Civil Society, Corporate Power, and Food Security: Counter-Revolutionary Efforts that Limit Social Change

Food is produced, processed, packaged, transported, and sold in a stable, organized system, or food regime. The current food regime is focused on calories empty of substantial nutrition designed primarily for the growth of capital and corporate power, fostered through the lax, often corporate-designed, regulatory environment of neoliberalism. The neoliberal food regime is responsible for systemic malnutrition and erosion of the ecological preconditions for food production, as a regularity of the system itself. Consequently, a main line of food vulnerability is the political system that insulates the current food regime from social forces demanding change. This insecurity is contrary to the public or larger human interest, but this unsustainable system remains in place through a stable arrangement of government prescriptions that follow corporate elite interests. To understand this structural problem, this essay examines the power of the food industry which requires the manufactured consent of civil society. The paper finds that counterrevolutionary efforts, which are anticipatory and reactive efforts that defend and protect capitalist elite from social change, stabilize the neoliberal food regime through covert tactics meant to undermine public interest critics and activists. As a result of these elite-led interventions, true civil society has become less powerful to articulate a public interest that might otherwise intercede in the operation and structure of the food regime. Thus, one leverage point in this political problem is the capacity of civil society, once it is independent of corporate interests, to remove consent to an abusive system and to debate and demand a food system that neither systematically

starves whole groups of people nor destroys the ecological systems that make food possible. Building food security, then, requires recapturing a semi-autonomous civil society and eliminating domination of the corporate elite, and replacing it with a politics aligned with a public and ecological affinity. Scholars, educators, and the public, can reduce the food vulnerability by becoming aware of corporate interests, and creating strategic alliances to form a new system with more humane and ecological priorities.

Evan Fraser, Alexander Legwegoh, K.C. Krishna (University of Guelph)

Food Stocks and Grain Reserves: Evaluating whether Storing Food Creates Resilient Food Systems

Many are worried that the global food system is entering a period of intense volatility driven by a combination of climate change and population growth. One way to address this problem is for governments and the international community to store more food as a buffer against crisis. The purpose of this paper is to explore the role of food storage as a component of a robust food security strategy in the 21st century. We do this by first drawing on historical evidence and examples from ancient Rome and China, where pre-industrial government designed extensive systems that ensured adequate food storage to keep food systems stable. Next, we review the links between food storage and price volatility in the last 20 years and demonstrate that the size of food stores (and in particular grain reserves) directly relates to price volatility. Third, we explore three different types of policies designed to promote grain reserves, the U.S.'s “ever-normal granary” policy, the EU's Common Agricultural Policy, and Strategic Grain Reserve in Africa. In this third section, we show how there has been a decline from state owned strategic grain reserves in favor of a more market-oriented approach that is dominated by a handful of powerful corporations who maintain sophisticated supply chains. Because data on the amount of food supply these corporations hold in storage are proprietary secrets, it is impossible to assess how resilient or vulnerable this makes our food system. Finally, we conclude that over time food storage has fallen in and out of favor, criticized for being expensive yet often shown to play an important role in protecting poor consumers in times of food crisis. Given the lack of data on current levels of supply chain and household storage, more research is needed to evaluate the scale at which food storage systems should be implemented to ensure food system resilience as well as mechanisms to govern and manage them.

Sarah Rotz, Evan Fraser (University of Guelph)

Resilience and the Industrial Food System: Analyzing the Impacts of Agricultural Industrialization on Food System Vulnerability

The purpose of this paper is to explore how socio-economic and technological shifts in Canadian and American food production, processing and distribution have impacted resilience in the food system. First, we use the social ecological systems literature to define food system resilience as a function of that system's ability to absorb external shocks while maintaining core functions, such as food production and distribution. We then use the literature to argue that we can infer food system resilience by exploring three key dimensions: (1) the diversity of the food system's components, (2) the degree to which the components are connected, and (3) the degree of decision-making autonomy within the food system. Next, we discuss the impacts of industrialization on these three factors within Canada and the US. Specifically, we show how processes of corporate concentration, farm-scale intensification, mechanization, and the “cost-price squeeze” have led to a decrease in ecological and economic diversity, a high degree of spatial and organizational connectivity, and a diminished decision-making capacity for individual farmers. While this analysis is qualitative and heuristic, the evidence reviewed here leads us to postulate that our food system is becoming less resilient to external shocks such as climate change. We conclude by discussing four possible strategies to restore resilience, and suggest a more transformational shift in food system politics and practice. Specifically, we argue that publicly led multifunctional policies may support more diversified production while programs to promote food

system localization can increase farmer autonomy. However, these shifts will not be possible without social-structural corrections of current power imbalances in the food system. This policy discussion reinforces the value of the social ecological framework, and specifically its capacity to produce an analysis that interweaves ecology, economy, and power.

Jennifer Hodbod, Hallie Eakin (Arizona State University)

Adapting a Social-Ecological Resilience Framework for Food Systems

The purpose of applying social-ecological resilience thinking to food systems is twofold: first, to define those factors that help achieve a state in which food security for all and at all scales is possible and second, to provide insights into how to maintain the system in this desirable regime. However, the resilience of food systems is distinct from the broader conceptualizations of resilience in social-ecological systems because of the fundamentally normative nature of food systems: humans need food to survive, and thus, system stability is typically a primary policy objective for food system management. However, society also needs food systems that can intensify sustainably, i.e., feed everybody equitably, provide livelihoods, and avoid environmental degradation while responding flexibly to shocks and uncertainty. Today's failure in meeting food security objectives can be interpreted as the lack of current governance arrangements to consider the full and differential dimensions of food system functions—economic, ecological, and social—at appropriate scales: in other words, the *multifunctionality* of food. We focus on functional and response diversity as two key attributes of resilient, multifunctional food systems, respectively, the number of different functional groups and the diversity of types of responses to disturbances within a functional group. Achieving food security will require functional redundancy and enhanced response diversity, creating multiple avenues to fulfill all food system objectives. We use the 2013–2015 drought in California to unpack the potential differences between managing for a single function—economic profit—and multiple functions. Our analysis emphasizes how the evolution of the Californian food system has reduced functional and response diversity and created vulnerabilities. Managing for the resilience of food systems will require a shift in priorities from profit maximization to the management for all functions that create full food security at multiple scales.

Part 2 (Journal of Environmental Studies and Sciences, Volume 5, Issue 4)

Gerald Marten (EcoTipping Points Project), Nurcan Atalan-Helicke (Skidmore College)

Introduction to the Symposium on American Food Resilience (Part 2)

The security of the U.S. food supply faces unprecedented challenges due to changes in our food system and the environment during recent decades. The 27 articles in the Symposium on American Food Resilience examine the resilience of food production and distribution – the system's ability to withstand shocks or stresses that could lead to disruption of the food supply. Four central questions provide a framework:

1. What are the main lines of vulnerability and how do they function?
2. What are leverage points for reducing the risks and improving the capacity to cope with breakdowns?
3. What is already being done by government, civil society, and the private sector?
4. What can scientists, teachers, and other professionals do through research, education, community action, or other means to make the food system more resilient?

The Symposium is in two parts. Part 1, which was published in the last issue of this Journal, laid out a conceptual framework and surveyed the problems. Part 2, which is in this issue, focuses on solutions. Paradigm shift is a major theme in Part 2. It revolves around two key ingredients:

1. Conflict between the prevailing “industrial” paradigm and sustainability
2. The scale of food system operations, and the contribution that more resilient regional food systems can make to the security of our food supply

Concrete details are provided by case studies from New England, Ohio, North and South Carolina, and Wisconsin, where researchers or nonprofit organizations have collaborated with food system practitioners to strengthen and diversify regional food production and food supply chains. A case study from Washington applies the diversity perspective to a strategic analysis of regional capacity for disaster response. Resilience planning in Australia features strategic policy analysis with quantitative techniques such as linear programming optimization and system dynamics, which can profitably be employed elsewhere as well. Together, the Symposium articles provide a bounty of material that can be mined by researchers, teachers, policy makers, farmers, and other food system practitioners for application to their own circumstances.

Molly Anderson (Middlebury College)

The Role of Knowledge in Building Food Security Resilience across Food System Domains

Food systems are social-ecological systems essential for human life. Many food systems are in parallel operation globally, differing in their practices, impacts, use of knowledge, and resilience. Those that are adapted to local constraints and assets and intentionally use and preserve ecosystem services result in lower environmental impacts and are less prone to lead to catastrophic environmental thresholds. Actors within food systems are constantly changing their practices to adapt to pressure and perturbations. Changing activities are correlated with changes in knowledge systems as well. Contributions to the resilience of social-ecological systems have been identified and evaluated, primarily based in ecosystem studies. Many of these attributes (e.g., memory, learning, self-organization) have to do with forms of knowledge. This paper suggests characteristics of “resilient knowledge” and links it with enabling power to make needed changes. How can this enabling power allow social organizations from the community to the international scale to build resilience to all kinds of perturbations into their food systems and create the knowledge systems that resilience requires? This paper compares knowledge generation, transmission, access, and use in four food system domains (global industrial, independent commercial, local and sustainable, and fair trade) discriminated on dimensions of globalization and multifunctionality. The objective of these comparisons is to understand connections among the resilience of food systems, food security, and knowledge systems. The paper concludes with a case study of the Committee on World Food Security (CFS), hosted by the United Nations Food and Agriculture Organization. The CFS embodies and facilitates many of the attributes of resilient knowledge generation and access; some of the tensions within the CFS reflect whether knowledge used by the Committee will have attributes of resilient knowledge. I argue that forms of knowledge generation, transmission, and access must be participatory, multi-actor, iterative, and transparent in order to build food security resilience. I also argue that knowledge at multiple scales must be resilient and interlocking in order to protect social organizations from food shortages and impaired food security.

Robert Dyball (Australian National University)

From Industrial Production to Biosensitivity: The Need for a Food System Paradigm Shift

Urban consumers in affluent cities are typically divorced from the landscapes and farmers that produce their food. Most food is made available to these consumers via global retail systems, operating within an overarching paradigm of industrial commodity production. This paradigm induces one-way flows of resources from rural hinterlands to cities, with farmers undercompensated for their services—a process which is inherently unsustainable and unjust. By unwittingly eroding processes upon which they are utterly dependent, urban consumers are making themselves vulnerable. Potentially, this vulnerability could be reduced if urban food consumption was linked to regional production, but for many cities, the

volumes of food required do not match regional output. Framed using a human ecological systems-based template, this paper presents case studies of three cities that have contrasting relationships with their regional food-producing landscapes. Canberra, Australia, could not consume all its regional production and so is in food surplus. Tokyo, Japan, could not meet its consumption needs from its region and so is in food deficit. Copenhagen, Denmark, could probably meet its needs from its region but chooses to reduce its food-producing land area and focus production on high-value meat products from pigs fed on imported low-value grains. Despite their differing food procurement strategies, producers and consumers in all three cases remain co-dependent upon each other and vulnerable to the processes being driven by the industrial paradigm. Consequently, a shift to a new 'biosensitive' paradigm is required, within which the social and environmental aspects of food production and consumption would be respected. This paradigm shift would reduce food choice and convenience and likely increase cost, so what would motivate consumers to support it? The answer suggested is that consumers could embrace the new food system if it had features that they valued sufficiently to compensate for the forgone values of the old system. Features that consumers could positively value include personal skills in the creation of meals, knowledge of the provenance and production standards of ingredients, and convivial relationships with producers. Pragmatically, these values are most likely to arise from consumers interacting with local food systems. Hence, it is argued, the primary value of local food systems lies not in the absolute volumes of food that they produce but in their educative capacity to foster a shift to a biosensitive paradigm. This new paradigm could extend concern to all food-producing landscapes and farmers, wherever on the planet they were located.

Laura Lengnick (Appalachian Sustainable Agriculture Project), Michelle Miller (University of Wisconsin), Gerald G. Marten (EcoTipping Points Project)

Metropolitan Foodsheds: A Resilient Response to the Climate Change Challenge?

The twenty-first century challenges of climate change and resource scarcity bring a new urgency to the widely recognized sustainability challenges of the US food system. Environmental and social impacts associated with the geographic concentration and specialization in production, processing, and distribution that accompanied industrialization of the US food system have degraded our nation's capacity to adapt to changing climate conditions. A consensus is emerging in sustainable food system scholarship that two fundamental changes—a transformation of production methods from industrial to sustainable and a transformation of food system geography from regional specialization to regional diversity—should enhance the resilience of the food system to climate change. A review of the literature suggests that transition to a nationally integrated network of sustainable metropolitan food systems ("metropolitan foodsheds") would improve climate resilience by enhancing three key qualities associated with resilience in social-ecological systems—diversity, modularity, and balanced accumulation of capital assets. These qualities promote the capacity of a system to respond, to recover, and to transform in ways that reduce damaging effects and take advantage of opportunities created by change. Using a set of behavior-based resilience indicators in a review of case study research, this article examines the general resilience of sustainable production and supply chain systems. Sustainable production systems managed by award-winning sustainable food producers expressed all of the behaviors of a resilient system and demonstrated remarkable resilience to weather variability and extremes. These producers attributed the climate resilience of their farms and ranches to high-quality soils, planned biodiversity, and diversified marketing. Like many sustainable producers, these farmers and ranchers not only produce crops and livestock, they also participate in processing, distribution, and retailing. Resilient behavior was also expressed in sustainable supply chains developed by networked community cooperatives and through government investment in a large nonprofit food terminal. As recent food system planning projects in the USA illustrate, there is growing recognition of the potential sustainability and resilience benefits of regional food systems designed to develop positive relationships

between the metropolitan core and surrounding areas. We can begin now to shift public support for a transition to more diversified production, to develop regional food system infrastructure, and to conduct comprehensive research to refine resilience indicators and develop food system performance metrics to guide a transformation of the US food system to a more sustainable and resilient future.

Brett Tolley (Northwest Atlantic Marine Alliance); Regina Gregory, Gerald Marten (EcoTipping Points Project)

Promoting Resilience in a Regional Seafood System: New England and the Fish Locally Collaborative

This article explores problems and solutions in the New England groundfish fishery, where social, economic, environmental, and food system sustainability are major challenges. With industrialization of fishing during the past century, managers have turned a blind eye to issues of scale (e.g., industrial scale vs. community scale), which has led to chronic overfishing. There have been recurring stock collapses of favored species (e.g., cod) during the past 50 years despite federal government management of the fishery during most of that period. Small- and medium-scale fishermen—with better local knowledge, motivation for local sustainability, and smaller ecological footprints—have increasingly been displaced by large-scale operations, especially during recent years with policies that are privatizing fisheries access and consolidating the fleet. Coastal fishing communities and the fishery have suffered. The Fish Locally Collaborative (FLC)—an international decentralized network of fishermen and their allies—is promoting a paradigm shift. Its efforts to keep the smaller-scale boats afloat and support local communities include economic and political strategies. Defining value with quadruple bottom line accounting (i.e., assessing social, economic, environmental, and food system impacts), the FLC promotes a shift from high-volume/low-value production to low volume/high value. The FLC has reestablished local food supply chains with community-supported fisheries, public seafood markets, and “boat-to-hospital” and “boat-to-school” programs based on procurement contracts that specify local and sustainable catch. FLC participants promote the consumption of lesser-known fish species to motivate more balanced and ecologically sustainable fishing. Politically, FLC participants continue to build the strength of the network and engage in policy discussions at local, national, and international levels.

Janet MacFall, Steve Moore (Elon University); Todd LeVasseur (University of Charleston); Jennifer Walker, Joanna Lelekacs (North Carolina State University)

Toward Resilient Food Systems through Increased Agricultural Diversity and Local Sourcing in the Carolinas

Biological and agricultural diversity are connected to food security through strengthened resilience to both anthropogenic and natural perturbations. Increased resilience to stress via increased biodiversity has been described in a number of natural systems. Diversity in food production can be considered on the following three levels: (a) genetic diversity as reflected in the range of cultivars which can be selected for production; (b) species diversity, captured through production of a wide range of crops on each farm; and (c) broad ecosystem diversity, described by the diversity of production between farms and within the broader food system. A network of locally based food producers and entrepreneurs provides opportunity for high diversity at each network stage, with increased adaptive capacity and the ability for rapid response to disturbance. We argue that production techniques that use carefully planned diverse plantings, such as biointensive cultivation, increase resilience by increased water use efficiency, yield and nutrient retention while reducing pressure from pests and pathogens. We present a model for a diverse, distributed food system in the North Carolina Piedmont and analyze an existing distributed network by a food hub in South Carolina. Through these models, we argue that a shift in the food network has the potential to increase local food security by having food more reliably available where it is needed and by contributing to local resilience through community economic development. The shift in food production and distribution systems serves multiple goals: When crop loss occurs,

other crops still contribute to overall harvest, reducing net loss. Diverse on-farm production can support a more distributed network of food aggregators, processors, and markets than the current approach of large-scale consolidation. Finally, a distributed food supply network supported with diverse agricultural products can increase resilience by providing access to diversified markets for producers and improved food access to consumers with more food choices, while expanding the need for skilled jobs supporting the regionally based food industry.

Casey Hoy (Ohio State University)

Agroecosystem Health, Agroecosystem Resilience, and Food Security

This paper lays out the relationships between three mutually reinforcing concepts associated with agroecosystems: (1) agroecosystem health, the extent to which an agroecosystem can meet human needs for all of its residents over time; (2) resilience, the capacity of a system to adapt, reorganize, and maintain key functions in the face of turbulent and unpredictable change in its environment; (3) food security, sufficient quantity and quality of food for everyone at all times. Agroecosystem health has been defined by a number of properties including the following: stability, sustainability, equitability, productivity, and autonomy, each in the context of specific spatial and temporal scales. Indicators that characterize biophysical and social conditions including soil health, biodiversity, topography, farm economics, land economics, and social organization can be combined using analytical hierarchy process to map agroecosystem health across a landscape. The resulting map may provide incentive and guidance for improving the conditions underlying agroecosystem health. Resilience and agroecosystem health overlap largely because both rely on diversity, in biological and physical as well as human cultural, social, and economic terms. The Agroecosystems Management Program at The Ohio State University has approached research and outreach to improve agroecosystem health, resilience, and food security by encouraging self-organizing social networks for economic development around local and regional agricultural supply chains, encouraging farm enterprise diversity at a wider range of farming scales, and conducting research to monitor and estimate the benefits of such diversification. Social media tools have been explored for connecting entrepreneurs at the planning stage, with the ultimate goal of improving the economic support for more diversified enterprises in agroecosystems. Although challenging, such adaptive management experiments may create and encourage new opportunities for managing agroecosystem health, and with it, resilient food production and security.

Nurcan Atalan-Helicke (Skidmore College)

Seed Exchange Networks and Food System Resilience in the United States

Seed exchange is a multidimensional issue with social, political, economic, and agricultural implications. There is a growing concern about the increase of the food system's vulnerability as a result of loss of agricultural biodiversity. Farmers' ability to replant, exchange, and distribute saved seed is a way to minimize their dependence on commercial suppliers and thereby maintain control over farming practices. Seed saving is also crucial for conservation because the process of choosing, replanting, and exchanging seeds relies on and increases diversity on the farm and in communities. Seed exchange networks, formal and informal ways that farmers engage alongside institutional plant breeding systems, help to conserve agricultural, social, and cultural diversity and identity as well as enhance resilience against environmental and economic shocks. However, how to build resilient seed systems and move from the innovative but relatively isolated project activities of professionals and farmers to a situation where such approaches are scaled up and networked alongside formal and informal, national and international plant breeding mechanism are a concern. This paper examines grassroots seed exchange through seed libraries, the marketing of new varieties through seed companies, and hybrid civil society-business models to understand their financial and technical abilities as well as challenges they face. Seed exchange networks fulfill an important role in conservation of agricultural biodiversity and building

community resilience through their work on breeding, exchange, and propagation of regionally adapted open-pollinated seeds as well as advocacy on seed sovereignty and education on seed saving.

Kathryn Ruhf (Northeast Sustainable Agriculture Working Group)

Regionalism: A New England Recipe for a Resilient Food System

Regionalism is a framework for economic, policy, and program development that responds to regional characteristics, differences, and needs and encourages regional approaches and solutions. This paper suggests that acting regionally contributes to food system resilience. The author discusses attributes of regionalism and regional food systems and how they build capacity to withstand disruptions in the food system. Food system resilience entails reducing vulnerability to risks of disruption to the food supply and increasing capacity to withstand or adapt to such disruption. Regions are an effective scale to promote resilience through enhanced diversity, stability, and flexibility, appropriately scaled supply chains and infrastructure, and strong foundational relationships. These attributes are important to resilience in that they decrease dependence on "external" variables, such as long-distance transport of foods, and increase "internal" capacity to provide for the region and withstand natural and manmade disruptions. The region is a powerful scale to respond to disruption in that it addresses supply (volume and diversity) better than local; is more nimble and flexible than nationally and globally sourced food (even accounting for global supply chain "substitution"); and effectively fosters relationships, communication, and trust which are foundational for responding to change (disruption). This paper focuses on the New England region whose six states have a history of working together. It is also a region that exemplifies an area's ability to respond to disruption based on real and felt interconnectedness of rural and urban interests. As such, it is an ideal learning laboratory for applying regional approaches to food system resilience, approaches that can be of use elsewhere both nationally and internationally. The paper describes several initiatives in New England that exemplify regional thinking applied to food systems and how such thinking can foster resilience. Initiatives focusing on regionally focused food supply chains, increased regional production, access to farmland, and food system public policies illustrate how the government, the civil society, and the private sector can collaborate to strengthen food resilience.

Rebecca Dunning, Dara Bloom, Nancy Creamer (North Carolina State University)

The Local Food Movement, Public-Private Partnerships, and Food System Resiliency

Concentration and consolidation in production, distribution, and retailing have arguably reduced the diversity of US food supply and distribution channels, thus introducing vulnerabilities into the food system. This paper addresses the question of what can be done to make the system more resilient to shocks that can disrupt food supplies. We suggest that the interest connected to the local food movement extant in a wide-ranging set of public and private groups, as well as among a widening base of consumers, creates a unique opportunity to strengthen food system resiliency. We specifically focus on the supply and distribution systems of supermarket retailers. Supermarkets are major drivers of the modern food system, with US and global consolidation positioning grocery retailers as both oligopolistic sellers and oligopsonistic buyers of food. We discuss the opportunities and challenges to diversifying supermarket procurement and distribution through localization and suggest that such a shift can be most successful if it is facilitated by public-private partnerships to foster system-level change. We provide an example of one such public-private partnership in the context of the work of the Center for Environmental Farming Systems (a collaboration between two North Carolina land grant universities) which has partnered with a regional supermarket chain to facilitate and promote the sourcing of local products. The substantive activities of the partnership—capacity-building training for growers and buyers, networking and peer-learning activities and site tours, support for MBA research teams and undergraduate internships, and piloting and subsequent evaluation of novel distributional techniques—are ones that can be enacted by researchers, instructors, and advocates in partnership with

supermarkets and other food businesses to build more resilient systems of food procurement and distribution. Discussion of the project provides tangible examples of how public and private entities holding shared interests in local agriculture can partner as part of a holistic approach to diversifying and strengthening the food system.

Michelle Miller, Jeremy Solin (University of Wisconsin)

The Power of Story for Motivating Adaptive Response–Marshaling Individual and Collective Initiative to Create More Resilient and Sustainable Food Systems

What can environmental scientists and teachers do to make our food system more resilient in times of rapid change and food system failures? One low-cost and high-impact way is to encourage people to tell their stories of food and farming. Stories are one way we navigate complexity, and our food system is increasingly complex. Facilitating individuals and groups to talk about their experiences and direct observations is a powerful tool to help people understand their role in the food system. As each individual makes his or her own personal story explicit, they begin to listen to the stories of others and see how their daily choices shape the system. People are then in a position to better understand complexity and make conscious choices that support resilience and systemic change. We offer three cases in different contexts that illustrate how anyone can facilitate an adaptive response and what outcomes could be expected. The first case involves discussion of agricultural ethics in a children's classroom setting. The second shares experience of apple growers who wanted to reduce pesticide risk but were thwarted by the management complexity. The third case brought together business leaders interested in making regional food systems more resilient. In these cases, narratives based on personal experience helped people understand their role as a central actor in the food system and make them conscious of their responsibility for the health of the system. It encouraged their curiosity and interest in specific questions that scientific inquiry could address. Storytelling empowered people to act individually and collectively to make the food system more resilient within their spheres of influence and built the skills necessary for effective civic engagement on complex systemic issues.

Rebekah Paci-Green, Gigi Berardi (Western Washington University)

Do global food systems have an Achilles heel? The potential for regional food systems to support resilience in regional disasters

Today's domestic US food production is the result of an industry optimized for competitive, high yielding, and high-growth production for a globalized market. Yet, industry growth may weaken food system resilience to abrupt disruptions by reducing the diversity of food supply sources. In this paper, we first explore shifts in food consumption toward reliance upon complex and long-distance food distribution, food imports, and out-of-home eating. Second, we discuss how large-scale, rapid-onset hazards may affect food access for both food secure and insecure households. We then consider whether and how regional food production might support regional food resilience. To illustrate these issues, we examine the case of western Washington, a region not only rich in agricultural production but also threatened by a Cascadia Subduction Zone earthquake and tsunami. Such an event is expected to disrupt transportation and energy systems on which the dominant food distribution system relies. Whether a regional food supply—for the purposes of this paper, defined as food production in one or adjacent watersheds—can support a broader goal of community food resilience during large-scale disruption is a key theme of our paper. The discussion that ensues is not meant to offer simplistic, localist solutions as the one answer to disaster food provision, but neither should regional food sources be dismissed in food planning processes. Our exploration of regional farm production, small in scale and flexible, suggests regional production can help support food security prior to the arrival of emergency relief and retail restocking. Yet in order to do so, we need to have in place a robust and regionally appropriate food resilience strategy. This strategy should address caloric need, storage, and distribution,

and, in so doing, rebalance our dependence on food supplied through imports and complex, domestic supply chains. Clearly, diversity of food sourcing can add redundancy and flexibility, allowing more nimble food system adaptation in the face of disruption.

James Ward (University of South Australia)

Can Urban Agriculture Usefully Improve Food Resilience? Insights from a Linear Programming Approach

Rising food prices and economic stagnation mean that access to affordable, nutritious food is a real problem, even in high-income countries such as the USA and Australia. It is claimed that urban agriculture (UA) reduces food costs and therefore has a role in improving household resilience during economic hardship. However, there is scant data to suggest that UA can appreciably improve household self-sufficiency in a crisis. This paper addresses the gap between claims and reality when it comes to UA actually reducing food costs. Using linear programming (LP), factors such as crop yields, food prices and inputs (such as irrigation water) can be quantified realistically, and an objective (e.g. overall diet cost) can be optimised. Constraints are applied to force the UA production regime to conform to a balanced diet. Subject to these constraints, optimisation yields a best-case estimate of the outcome, so can be seen to provide a "cautiously optimistic" result.

The model is run for a case study in Adelaide, South Australia, and results suggest a typical high meat consumer could reduce their food cost by approximately 10 % with substantial home food production (including intensive poultry rearing for meat). Meanwhile, a shift in diet towards vegetarianism would deliver twice the saving, with a further 10 % achievable through UA. In the context of resilience, the results suggest that households could save a modest amount of money through dietary change and by growing some of their own food. The modelling revealed a trade-off between cost-saving and self-sufficiency (measured as percentage of home-grown dietary protein), but growing 10–15 % of dietary protein on 40 m^2/person appears plausible without sacrificing financial savings. Optimisation represents a quantitative framework that is suitable for a variety of extensions to help ground claims being made around UA and local food production, such as investigating the potential for reducing dependence on transport by provisioning food from within and around a city. The model would be greatly improved with more accurate data on yield, water and fertiliser inputs.

Seona Candy, Che Biggs, Kirsten Larsen, Graham Turner (University of Melbourne)

Modelling Food System Resilience: A Scenario-Based Simulation Modelling Approach to Explore Future Shocks and Adaptations in the Australian Food System

This paper outlines a process for exploring food system vulnerability and resilience using scenario modelling with the Australian Stocks and Flows Framework (ASFF). The capacity of ASFF to simulate how diverse shocks and stressors affect food system behavior across multiple sectors – with diverse, interconnected and dynamic variables shaping system response – renders ASFF particularly suited for exploring complex issues of future food supply. We used ASFF to explore the significance of alternative agricultural policies for land use, crop production, livestock production, fisheries, food processing, transport, food waste, and ultimately food supply. Policies in different scenarios varied with regard to the timetable for reducing greenhouse gas emissions, the degree of government participation or regulation in the food system, and the scale of solutions (varying from centralized and global to decentralized and local). Results from the scenarios suggest that Australia does not have the ability to maintain a domestic surplus of foods required for a nutritious diet. In particular, the health of the current food system is highly vulnerable to constraints in oil supply, and increased food production threatens to precipitate a drastic decline in critical water supplies. We conclude by outlining a proposed method for using ASFF to delve deeper into the dynamics of the food system, probe the consequences of various adaptive responses to food production and supply challenges, and devise potential indicators

for food system resilience. Shocks and stressors to be added to the next phase of scenario modelling include soil salinity, climate extremes, and credit scarcity. The ASFF methodology should be applicable to other parts of the world, although appropriate recalibration and adjustment of model assumptions would be required to reflect regional differences.