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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

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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 (Online Resource 1; Endres and Endres 2009; Ladner 2011). Difficult-to-predict disturbances such as energy crisis, severe draught 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.

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 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 Online Resource 1 for a complete record of the presentations and discussions.) 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 at Online Resource 3.

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.

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

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

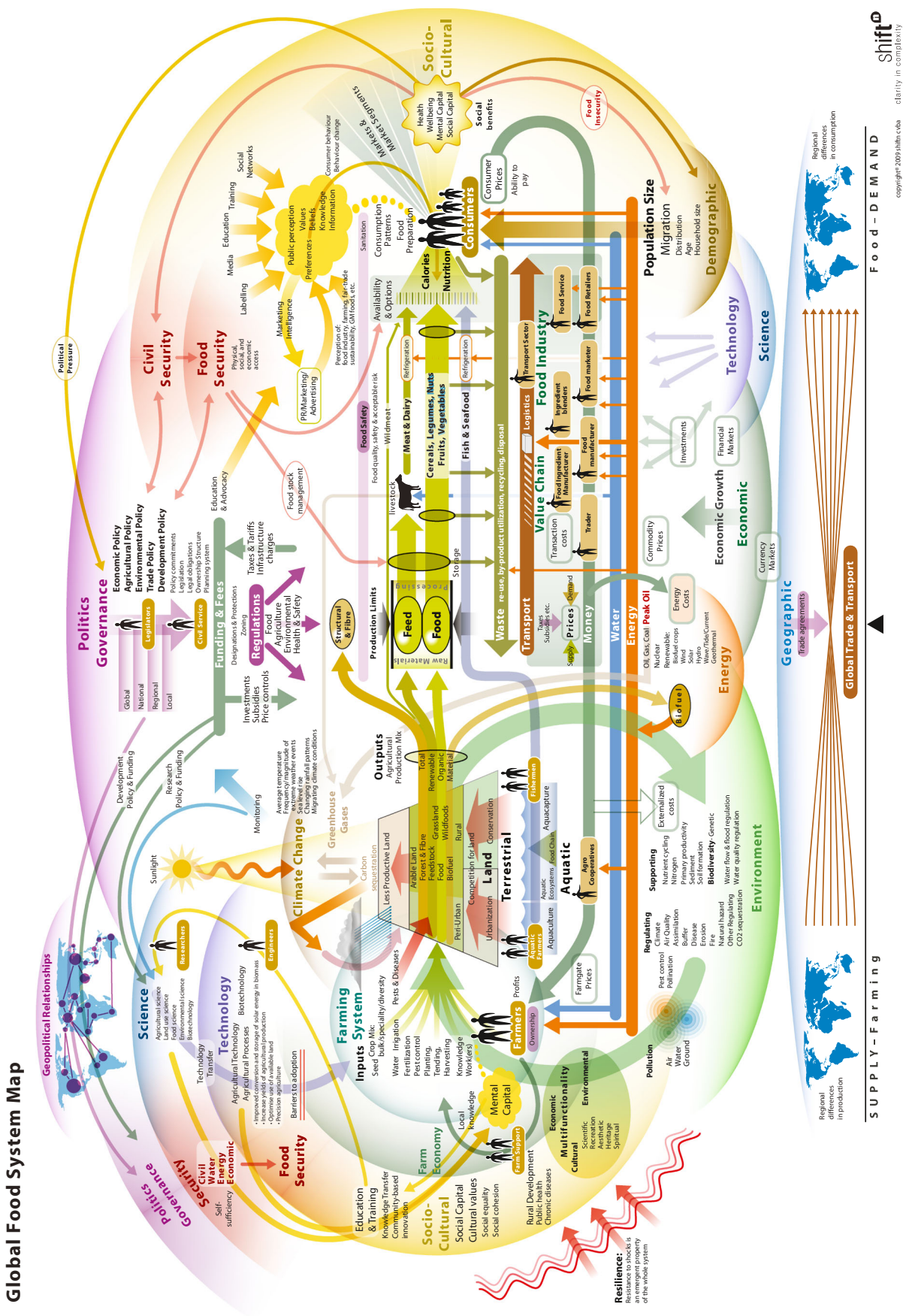

Fig. 1 The food system with its numerous flows and cause-and-effect relationships. Source: shiftN (http://shiftn.com). Flows along food supply chains (Pullman and Wu 2012), from farms to processing and packaging, distribution, retailers, and consumers are shown as "value chain" in the diagram. Details of this diagram can be seen in a high-resolution image at Online Resource 2

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.

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,

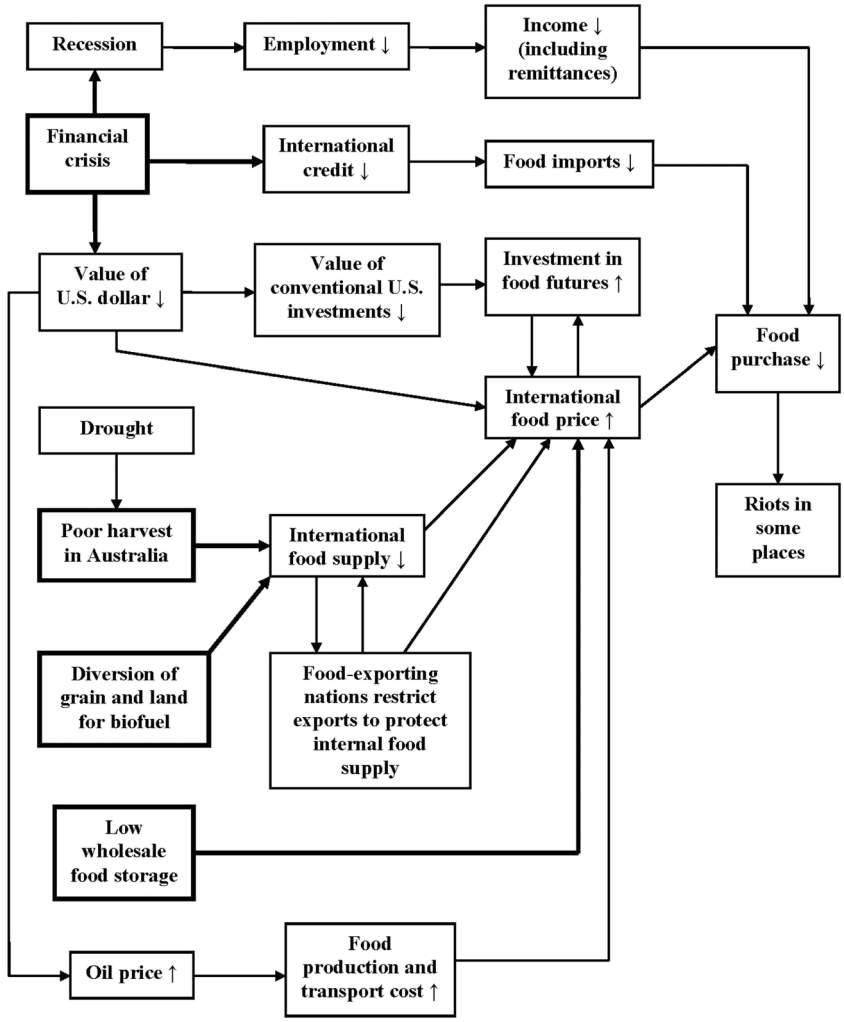

Fig. 2 Increase in international food commodity prices triggered by poor harvest in Australia and diversion of grain to biofuel and exacerbated by the financial crisis, an increase in the oil price, and low wholesale food storage. *Arrows* inside the *boxes* show the direction of changes (increase or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

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

Table 1 Overview of articles in the Symposium on American Food Resilience (part 1)

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

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Table 2 Overview of articles in the Symposium on American Food Resilience (part 2)

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 (2015c)	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
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)	Draws upon messages from all symposium articles to enumerate key issues, probe questions that they raise, and outline key concepts and action strategies for improving American food resilience

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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).

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.

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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