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Agro Terrorism: A Global Perspective

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Abstract

The global food supply chain remains a significant target for those who want to cause fear, harm or destruction to our sustenance of life and liberty. When naturally-occurring animal outbreaks, such as foot and mouth disease, avian influenza, chronic waste disease, swine flu, or the many animal and crop diseases and pathogens are added to the list of potential security concerns and threats, biosecurity and bioterrorism assume a greater significance in a nation's effort to effectively secure their homeland. Information and intelligence gathering, policy decisions, target hardening, and resource allocation become linchpins for effective homeland security. This paper discusses global agricultural security risks within the milieu of agro terrorism as a threat to biosecurity. It briefly presents the disease agents which potentially undermine public health and social, political or economic stability of given regions throughout the globe, threaten a society's confidence in their government, disrupt the food supply chain, or create fear and panic. Finally, the effect of various outbreaks and attacks are presented as case illustrations.

Keywords: Agro terrorism; Animal diseases; Biosecurity; Bioterrorism; Plant pathogens; Risk assessment

Introduction

The global food supply is a potential target for any actor who seeks to cause death and destruction, fear and intimidation, coercion, or political, social, or economic disruption. Terrorists have attacked groups of people by donning and detonating explosive vests, driving chemical-filled trucks into crowds of people, surprising shoppers with bursts of automatic weapons, resorting to knife attacks, or piloting jet airliners into buildings to complete their mayhem. Homeland security efforts recognize that terrorists consider a wide array of methods to inflict damage, so they persistently seek information and intelligence. The availability of chemical, biological, radiological, nuclear, or explosive (CBRNE; weapons of mass destruction) agents and their unconventional manipulation pose a threat to any country's critical infrastructure. Much of the public and international discussion over terrorist methods does not substantially weigh attacks on food and agriculture [1-5]. This manuscript defines significant plant and animal threats to food and agriculture, the effect of an outbreak to the global food supply chain, and the economic impact of dangerous plant and animal pathogens. It provides case illustrations of natural and man-made attacks, and establishes policy and a framework for the security effort needed to surveil, respond to, and manage plant and animal outbreaks and threats.

Methodology

This study relied upon open-source literature and information from government and non-governmental reporting agencies available through the world-wide web, university web-based databases, and subject matter experts, including research institutions and scientific research laboratories. Examples of the sources include the World Health Organization, the World Research Institute, the United Nations Environment Programme, the French Agricultural Research Centre, the World Organization for Animal Health, the Department of Homeland Security, the U.S. Centers for Disease Control, National Center for Infectious Diseases, Department of Justice, Food and Drug Administration, Department of Commerce, American Geological Society, and the Department of Agriculture. Search terms and the scope of the research included biological agents, agro terrorism, and attacks on crops, food and livestock. The research effort involved reviews of the prevalence and incidence of food safety threats, identified pathogens, and case studies and illustrations needed to guide the research project and establish a framework for the effective security protocol. Additional search terms were multidisciplinary in nature, and included terrorism, transnational crime, bioterrorism, biowarfare, and biotoxins. A substantial amount of literature was extracted from homeland and national security publications and included information from disciplines related to public health, agriculture, food and crop supply, and weapons of mass destruction.

Terms and Definitions

Agro terrorism

"Agro terrorism is a subset of bioterrorism, and is defined as the deliberate introduction of an animal or plant disease with the goal of generating fear, causing economic losses, and/or undermining social stability" [6,7]. Agro terrorism may include the use of any pathogen to contaminate a nation's food supply, the supply chain, or the spread of contagious diseases through the food supply. The deliberate introduction of detrimental agents, biological and otherwise, into agricultural and food processing systems may be directed toward specific, or broad areas of the food and agricultural infrastructure, including the food chain, and may include targeting of farm animals and livestock, plant crops, and the food processing, distribution, and retailing system" [8,9].

Bioterrorism

Bioterrorism is a specific form of terrorism involving the deliberate environmental release of pathogens (viruses, bacteria, parasites, fungi, or toxins) causing illness or death in people, animals, or plants. Dissemination is accomplished through the release of aerosols, as an addition to an explosive, as a foodborne substance, through deliberate human interaction, through a vector, zoonotically, or through food and water contamination [10].

Several factors affect the classification of biological agents. They include the ease of transmission, their effect on mortality and the potential for a major public health impact, the level of social disruption and panic, and the manner of response needed by public health and emergency personnel. Category A agents, the most dangerous, include smallpox, anthrax, plague, clostridium botulinum toxin (botulism), tularaemia, and viral hemorrhagic fevers, such as Ebola. Category B agents are moderately easy to disseminate, cause moderate morbidity and low mortality, and require enhanced disease surveillance. Examples include ricin toxin, salmonella species, and other agents. Category C pathogens are emerging strains which may be engineered for mass dissemination and future consequences; they include nipah virus, hanta virus, and tuberculosis. The U.S. Centers for Disease Control and Prevention report that zoonotic diseases, those spread from animals to humans, may account for more than 6 of every 10 known infectious diseases in humans, and 3of 4 new or emerging diseases spread between animals and people [11]. The World Health Organization generally classifies zoonotics as:

Bacteria: Anthrax, brucellosis, Escherichia coli, plague, tularaemia, salmonellosis, campylobacteriosis, shigellosis and leptospirosis, which cause fever, diarrhea, abdominal pain, malaise and nausea. Yersinia pestis may be transmitted to humans through a rat flea and rodents, and may take the form of a pneumonic, septicemic, and bubonic plague. The plague can also be transmitted when respiratory droplets of infected individuals or animals, including domestic cats, are inhaled. The lethality of the plague is between 50 percent and 100 percent of the infected population, when not properly treated [12-14]. The bubos (swollen, painful lymph nodes) may affect the groin area, armpits, or neck and progress to tissue bleeding, and gangrene. The WHO reported a 2014 bubonic plague in Madagascar, which injured 100 people and led to the deaths of 40 more, indicating a deficiency in security systems to control a centuries-old disease [15].

Parasites: Cysticercosis/taeniasis, trematodosis, echinococcosis/hydatidosis, toxoplasmosis, and trichinellosis, which cause seizures, headaches, and many other symptoms

Fungi: Dermatophytoses, sporotrichosis, which cause itching, redness, scaling, and hair loss

Viruses: Rabies, Avian Influenza, Crimean-Congo hemorrhagic fever, Ebola, and Rift Valley Fever, transmissible through bites from infected animals and leading to high mortality rates in animals and humans. Many viruses maintain short incubation period, 2 to 6 days, for example, and often reveal symptoms such as fever, headache, myalgia and backache. Other symptoms include diarrhea, vomiting, rash, and decreased functioning of the liver and kidneys. Some viral diseases are transmitted from animals to humans, often through insect or mosquito bites. Foot and mouth disease (FMD) is a severe, highly contagious viral disease which afflicts ruminants (e.g. cows, sheep, goats, deer, and swine). FMD affects the tongue, lips, mouth, mammary glands, and hooves, with vesicles, leaving weakened, lame livestock that is unable to produce milk or meat. Chronic wasting disease is a virus which affects the neurological system of wildlife and often leads to destruction of deer and elk herds [16-18].

Unconventional agents: Bovine Spongiform Encephalopathy (BSE) (potential cause of Creutzfeldt-Jakob Disease) leading to degenerative neurological disease and is inevitably lethal in humans [13].

Biosecurity: Biosecurity is a strategic and integrated defense approach that encompasses the policy and regulatory frameworks… (which) analyze and manage risks in… food safety, animal life and health, and plant life and health, including associated environmental risk" [19]. It includes efforts to control plant and animal pests and disease, zoonoses, the use of genetically-modified organisms and their products in an environment, and the introduction of invasive alien species and genotypes [20].

History and Context

War and conflict

The use of chemicals, infectious diseases and other pathogens on crops, animals, and humans is not a new phenomenon. The early documented use of fomites as a biological agent to harm a population involves the plague. "During the siege of Kaffa (now Feodossia, Ukraine) in 1346, the attacking Tatar force experienced an epidemic of bubonic plague" [21]. Attempting to turn the infection into a defeat for their enemies, the Tatars catapulted bubonic-diseased bodies of their fallen combatants into Kaffa, where Christians had received refuge. At the time, the plague had manifested upon China, India, and Persia, ultimately killing nearly half of the population in China alone. Maritime trade during this medieval period, no doubt included rat-infested vessels and the plague from fleas and possibly contact with the infected rodents. The Black Death, as it is known, reached Eastern Europe, the land area reaching the Black Sea, and the Crimean Peninsula. Historians and biologists are unsure if the plague was zoonotic, as sanitary and hygienic conditions at the time were poor, the fighters were exhausted, and ships traveling between ports were unknowingly transporting diseased refugees and parasites. Some Christians fled Kaffa and infected Constantinople, Genoa, Venice, and many Mediterranean ports. The death toll attributed to the plague was 60 million people. Currently, epidemiologists agree that catapulted, diseased cadavers could not have transmitted the plague because the parasites require a living host [22,23].

In contrast to the beliefs at the time, the bubonic plague is now known to have been a natural occurrence, particularly given the environmental conditions upon which it propagated. However, the first recorded biological agent "weaponized" for a nefarious purpose was the smallpox virus, transferred to blankets then given to Native Americans in North America during the French and Indian Wars (1754-1767). As fomites, the excretions and pus or dried scabs of British soldiers assigned at Fort Pitt (now Pittsburg, Pennsylvania) were placed on blankets and handkerchiefs. British commanders wanted to reduce the size of the Native American tribes due to their perceived hostilities to the British, so they transferred the virus through the linens they gifted. It is not known how effective the blankets were in killing the intended targets, but there were no known cures for smallpox at the time, and the dousing of cold water on the pox, a Native American ritual believed to control the disease, had no healing effect. Nonetheless, complications to the epidemiological investigation exist because there were outbreaks of the measles in 1759, as well as dysentery and flu, also potentially fatal. Importantly, the smallpox virus is more effective when dispersed through respiratory transmission, and the virus may not live more than 7 days under the conditions prevalent in 1754 [24,25]. Much later, during the Cold War, biological warfare programs, capable of reaching food and agriculture industries within any country, were present in many advanced and developing countries. The U.S., United Kingdom, the former Soviet Union and known conflict zones, such as South Africa, Syria, Iran, and Iraq are examples. In 1942, the U.S. Army Chemical Warfare Service was staffed with about 4,000 workers and a budget of $40 million. Its focus on anthrax and botulism is well-documented [26]. The U.S. and Russia are believed to have stockpiled wheat stem rust spores, capable of destroying an entire wheat crop. Likewise, China's biological weapons (BW) activities were reportedly extensive and often multi-purpose, aimed at multiple potential targets. In recent times, China's compliance with international conventions against biological and chemical weapons involved the destruction of about 350,000 chemical munitions left on its soil by Japan after WWII [15,27,28].

Several other illustrations of biological weapons programs during this time period involve the U.S.S.R., Japan, and Germany. The former U.S.S.R. possessed a well-funded weapons program focused on biological agents, including genetic engineering of pathogens which did not exist in nature [29]. By the end of WWII, Japan is believed to have had one of the world's most aggressive biological warfare programs. As many as 10,000 prisoners of war died in laboratory experiments, and several thousand others in military field operations. The zoonotic diseases used by the military were typhus, cholera, plague, anthrax, typhoid fever, glanders, and dysentery. Germany poisoned horses, mules, and donkeys used by Allied armies for the transportation of troops, munitions, and supplies, by feeding microbes to them [30].

Along with particular efforts to destroy the infrastructure, many warfare programs also experimented with virulent pathogens to destabilize and harm a country's economic, political, and social structure, as legitimate aims of warfare. With the negotiation of conventions, such as the Biological and Toxin Weapons Convention (BWC, 1972) many of the programs were curtailed. Similarly, the global concern over chemical weapons programs led to the 1993 Chemical Weapons Convention (CWC). Collectively, the BWC and CWC advanced the 1925 Geneva Protocol, forbidding the use of chemical and biological weapons in conflict [30,31].

Natural pathogens

Within the 20th Century, there have been many natural disease outbreaks to plants, animals, and humans. For example, the Spanish Flu pandemic (1918) occurred after the development of antibiotics to counter the effects of pathogens such as bubonic plague. The scientific community considers the bubonic plague to be the greatest single biological disaster in human history, killing between 30 and 40 million people worldwide, and about 600,000 in the U.S. alone [28].

Recent cases suggest that an outbreak can occur when weather conditions are conducive to widespread dissemination of pathogens. The virulent atypical pneumonia epidemic known as severe acute respiratory syndrome (SARS) infected 8,422 people throughout the world. It originated in China and killed 916 people before the pandemic was controlled. Avian influenza is another easily propagated disease, and it joins previously-controlled diseases, such as smallpox, measles, and Ebola, as a recurring disease. The diseases can quickly spread and affect many people. For example, in the U.S., during 2014,667 people were sickened with measles across 27 states. The same year, an Ebola outbreak affected over 15,000 people in West Africa, resulting in over 11,000 deaths [32-34]. The historical impact of naturally-occurring plant disease is also well-documented. "Fungi, water molds, bacteria, virus, nematodes, phytoplasmus, and parasitic plants" can be spread through the atmosphere, or through natural streams and rivers. An example is the chaos and calamity that may result from a natural outbreak involves the Irish potato famine of 1845, which led to the migration of over 1.5 million inhabitants to the United States and the loss of 1.0 million people when potato blight caused starvation [35].

Natural occurrences may also occur as unintended consequences or accidents. One such example involves the near extermination of an entire species. In the U.S., the American chestnut tree was struck by blight from the introduction of Chinese chestnut trees to America late in the 20th Century. Asian trees were more tolerant of blight, whereas chestnut trees, natural to the native forest habitat of the Northeastern U.S., were not. The trees served as hardwoods for construction and yielded significant chestnuts; however, by 1940, less than 40 years after infection, nearly 30 million acres and 3.5 billion of the hardwoods perished [36]. The trees were a necessary part of the ecosystem, providing large canopies for shade, nutrients, and cover for other plant species. Inoculation and the importing of hypovirulant disease resistant Italian trees slowed the blight in chestnut trees and helped derive more resistant trees.

Availability and potential

Biological agents may be inexpensive and rather easily acquired. Some are available as part of scientific research. Farming operations are open and vulnerable and thus exhibit multiple points of disruption [37]. The potential for an attack may be limited by how easily a pathogen may be weaponized and whether it may be delivered across large geographic areas. The ability of the pathogen to survive the environmental conditions may be a limitation, as is the non-discriminatory nature of the pathogen. Actors may potentially infect themselves, and since there is usually an incubation period, perpetrators may have traveled long distances before the symptoms of an attack are apparent, and victims and perpetrators may not immediately manifest the symptoms related to the pathogen released. Perhaps the greatest homeland security concern of a pathogenic attack on any part of a nation's food supply chain is the relative inability of public health and law enforcement authorities to quickly determine the etiology of an event or its epidemiology. Many identified epidemics and pandemics cannot easily be differentiated from naturally occurring events. Threats of biological agents are substantial because they often do not work immediately and are not detected easily. Instead, there is an incubation period, and the relative ease upon which they can be released makes them an attractive form of terrorism.

To illustrate the detection problem, consider the outbreak of Enterohemorrhagic E. coli (EHIC) disease in Germany. More than 4,000 people became ill and 52 later died from food related to a contaminated batch of fenugeek seeds imported from Egypt and harvested at a Hamburg farm. The food-borne pathogen occurred as part of salads available in restaurants. It "dramatically and rapidly… developed into a major health threat for an entire country" [38]. People infected with the illness exhibited bloody diahrrea and haemolytic uraemic syndrome (HUS), including nausea and vomiting. HUS is marked by thrombi in the capillaries, arterioles, and kidneys. It leads to varying degrees of kidney failure and primarily affects infants and young children. There is no prescribed cure for this disease [39].

The Global Food Supply Chain

The Food and Agriculture Sector represents a relatively soft target for terrorism because of its inherent characteristics. For example, each country throughout the world possesses a networked system of farms and ranches, processing facilities, and an elaborate system for manufacturing or harvesting, processing and packaging, distribution, and presentation for consumption. The Food and Agriculture Sector is intricately connected to private industry, the banking and financial system, energy sources, transportation, and water and sewer systems. When a foreign pathogen is introduced into the food and agriculture sector, plant and animals may be infected, but epidemics may follow, particularly if the environmental conditions allow it. "Historically, (the conditions for an epidemic, or pandemic, if localized to a particular global region) favor an isolated environment with animal or insect carriers, unsanitary conditions, and large human populations" [40].

Globalization and the advancements in technology have enhanced the ability of any country in the world to supply food or agricultural products to local, nearby regions, and faraway lands. "For countries with agriculture as a significant portion of their gross domestic product, disruptions anywhere along the food chain can lead to food insecurity and national instability" [41]. With the global population expected to reach 9.6 billion inhabitants by 2050, the challenge of providing adequate nutrition is compounded by the potential threat to any part of the supply chain [37,42]. Therefore, the farm or ranch, as well as any processing and packaging of products, the movement to distribution centers, transportation to retailers and wholesalers, and ultimately conveyance to the consumer all comprise the global food supply chain. Along with the corresponding movement and transfer of money there are concerns with respect to information and intelligence and the security of data, research, intellectual property, trademarks, formulas, and ingredients. At any point within the supply chain, there is the potential for an attack, destruction, disruption, and contamination and introduction of pathogens into the food or animal products, including the integrity of the food itself.

Researchers and policy analysts define the global food supply chain as the aggregate of agricultural production, industrial processing, and wholesale or retail distribution. Also, the full complexity of the global supply chain is appreciated when additional links and stages are considered, such as "arable land, water and genetic resources (a limited biodiversity)" [43].

The mapping of global distribution of food is a difficult task, but new statistical models, such as the Gridded Livestock of the World, v2 (GLW-2), provide context to explain and prepare security for modern societies. Urbanization, human population growth and increasing incomes lead to higher consumption rates of plant and animal-sourced foods. Statistical and forecasting models analyze livestock dispersion data and identify areas potentially susceptible to natural outbreaks. The effort is complicated when the extent of global output is concerned. For example, the world livestock population is comprised of 1.43 billion cattle, 1.87 billion sheep and goats, 0.98 billion pigs, and 19.60 billion chickens. The successful introduction of any pathogen to harm the herds in any region has the potential to cause widespread economic distress [44].

Economic Impact

Advanced, industrialized nations possess robust economies and gross domestic products. For example, Australia's Gross Domestic Product (purchasing power parity) is estimated to be $1.189 trillion, and the country engages an open market, free trade agreements with China, New Zealand, the Republic of Korea, Japan, Chile, Malaysia, Singapore, Thailand, Indonesia, and India [45]. It has an "Asia-wide Regional Comprehensive Economic Partnership that includes 10 ASEAN countries… and is engaging on the Trans-Pacific Agreement with Brunei, Canada… Mexico… Peru… the U.S., and Vietnam." Its trade involves the exporting of cattle, sheep, poultry, wheat, barley, fruits, and sugarcane [46]. Australia's agriculture and food industry represents a major part of the economy, with products ranging from cattle farming, production of grain, sheep farming and the dairy industry, for an estimated 135,000 businesses. The agricultural sector employs about 8.5 percent of the country's population and generates over $39.5 billion per annum.

The economic losses to healthy economies can be substantial; however, for developing and fragile countries, the losses may be devastating. Throughout history, many outbreaks of crop diseases have been associated with famine. In Ireland, potato blight in 1845 led to the starvation of one million people and the migration of 1.5 million inhabitants to the United States. The Bengal famine in India (1942-1943) resulted in the loss of nearly 2.0 million people. When countries rely upon its crop production for sustenance, and the crop is destroyed, widespread starvation results in many deaths. Developing and failing countries often do not have the fiscal ability to import other crops [47].

Even in highly developed countries, an uncontrolled outbreak may be devastating. The Foot-and-Mouth Disease (FMD) outbreak in the United Kingdom (UK) in 2011, resulted in losses of between $25-30 billion. The 2001 FMD outbreak in the UK was traced to the viral movement from the Eastern Mediterranean, Middle East, India, and Far East, where the virus spread since 1990. Other strains were observed in South America, Africa, Middle East and Far East. The source of the viruses was believed to be illegal imports and fomites, such as personal baggage or commercial consignments [48].

The FMD epidemic resulted in loss of tourism and trade, the slaughter of up to 100,000 livestock animals per day, and the culling of 6.0 million animals (4.9 million sheep, 700,000 cattle, and 400,000 pigs) [15]. Similarly, a 1996 FMD outbreak in Taiwan's swine stocks resulted in the destruction of nearly 4.0 million hogs, and loss to the Taiwanese economy of $7.0 billion [49]. In another comparative case of an outbreak, the SARS outbreak in China and Canada cost $30-50 billion in economic losses [50].

Boisvert et al. [51] applied a multi-region, multi-sector computable general equilibrium (CGE) statistical model of the global economy to estimate losses in the U.S. economy if a FMD outbreak were to occur. Such an outbreak would impact local, regional, and international markets with respect to raw milk, dairy products, and livestock sectors in the amount of $11.7 billion to the U.S. economy, and a $14.1 billion loss to beneficiary nations (Argentina, Brazil, Latin America, Australia, New Zealand, Canada, Mexico, and the European Union) [51]. Value-added losses and job income would reach $1.37 billion, including an estimated 12,000 job losses to food and agriculture workers. According to the U.S. Department of Homeland Security, the U.S. agriculture industry comprises a critical infrastructure which contributes over $1 trillion to the U.S. economy each year, including $150 billion in agricultural exports and an additional $190 billion in economic output [52].

Case Illustrations

Fruit contamination

In 1989, suspected cyanide contamination of grapes headed to the U.S. from Chile, led to an investigation by the Food and Drug Administration. The U.S. Embassy in Santiago had received a call that Chilean grapes were poisoned with cyanide. The contamination was limited to a few grapes shipped from Chile to Philadelphia, and not widespread exports; however, because many importing countries stopped fruit product exports from Chile, the Chilean agricultural industry suffered an estimated $300 million loss. Chilean fruit exports were the country's second largest exported commodity, next to copper. Because all fruit from Chile was suspected of contamination, the U.S. destroyed 45 million crates of fruit, including "nectarines, plums, peaches, apples, pears, raspberries, blueberries, and table grapes (amounting) to a loss of $50 million" [53].

Brucellosis: An epidemic of brucellosis in Northern Ireland peaked in 2002 when an average of 60 herds of livestock was destroyed to prevent further infections. However, in 2010, a foetus infected with brucellosis was found in a field among young heifers; it was covered in feed, obviously meant to attract cattle and cause infection [54]. Similarly, a calf's leg was found in silage fed to cattle in Armagh, causing widespread fear among farmers that the epidemic was not eradicated, and there would be further agricultural losses. While the investigation revealed that the leg did not contain brucellosis, about 12 herds per month were destroyed. There have been continued outbreaks and recrudescence since the 1980s, but between1999 and 2013, the livestock losses amounted to about £150million sterling [55]. Brucellosis is an infectious disease which affects livestock, such as cows, but can also infect dogs, swine, sheep, goats, and camels. Scientists confirmed new cases and strains involving the red fox, and marine animals, such as seals. Infected animals cannot be cured, so they must be destroyed [56].

According to the World Health Organization, brucellosis "causes flu-like symptoms, including fever, weakness, malaise, (abdominal and back pain, cough, headaches, night sweats) and weight loss," and in animals, it can "lead to decreased milk yields, infertility, weak calves and serious financial loss." Its incubation period is between 5 and 30 days. Infections have reached persons from 100 countries throughout the world, often in Latin America, the Middle East, India, Greece, and Spain. Brucellosis is transmitted through eating or drinking unpasteurized dairy products from infected animals, unpasteurized cheeses, and contact with infected animals and meats. Through effective surveillance programs, educational awareness campaigns, testing, and destruction of infected herds, N. Ireland was granted status as an official brucellosis-free country by the European Commission (2015). Northern Ireland's Department of Agriculture and Rural Development office worked with the European Commission's Standing Committee for Plants, Animals, Food and Feed to ensure all data sets and evidence supported the application and that an effective biosecurity program existed [15].

Frozen food contamination: In 2014, Japanese factory worker Toshiki Abe was sentenced to 3.5 years in prison for intentionally contaminating frozen food products with malathion. The malathion chemical is used as a pesticide to control a wide variety of insects, including mosquitos and fruit flies. The detected concentration levels of the poison were 2.6 million times higher than permitted by law. Since the frozen food processing company did not routinely use the insecticide malathion, the presence of the toxin at such a high concentration level constituted evidence that the act was deliberate. The actor's actions sickened as many as 2,500 people across Japan and amount to one of the most severe acts of intentional food product contamination. The products included pizzas, croquettes and pancakes, and led to acknowledgement by some premier hotels and stores that the food they had promoted was not what it had been billed to be. More than 6 million packages of frozen food were recalled and destroyed [57].

Policy and Biosecurity Framework

Increased knowledge, awareness, and effective responses to food and agricultural threats can be attributed to the improved public health signal detection, such as PulseNet, the regulatory reporting requirements for food products in the U.S. This involves "improved communication streams and interconnectivity between regulatory agencies domestically and internationally" [58,59].

Vulnerability and risk assessment are important concepts to consider in structuring a biosecurity framework. According to the RAND Corporation, key vulnerabilities in the agricultural sector stem from farming practices involving crowded breeding, rearing, transportation, and auction or sale conditions which might result in infections of normally healthy livestock. New veterinary practices and knowledge related to sterilization, dehorning, hormone injections, use of antibiotics may affect the health of the livestock (disease susceptibility). The wide variance of agricultural security and surveillance systems contribute to greater threats to small and medium sized operations. Infrequent surveillance and a lack of security protocols at food processing and packaging facilities may contribute to the spread of diseases. The attention given to animal behaviors and their health is an important safeguard to infections and diseases; however, while larger herds may not receive the surveillance needed to thwart disease, the smaller farm owners may lack an indemnity program and may thus have a disincentive to report animal disease [60]. Examples of policy may be established through interpretation of statutes, such as the U.S. Plant Protection Act (P.L. 106-224, Title IV, Sec. 402, 2000) and the Animal Health Protection Act (P.L. 107-171, Title X, Sec. 10402, 2002 which provide eradication and regulatory authority. The U.S. Agricultural Bioterrorism Act of 2002 (Subtitle B of P.L. 107-188), and the federal regulations pertaining to safeguarding systems. The U.S. Gray Book and the OIE Technical Disease Cards also establish guidelines for management of exotic pests and diseases [61].

Risk assessment models benefit from measures taken to identify early onset of behaviors and conditions that may indicate a threat. Signs and indicators of a problem may include threats, suspicious activity by workers, neighbors, or family members and associates. Effective models consider the virulence of the agent, host susceptibility, context, and interaction of the pathogen, host, and environmental conditions. Crops will also likely reveal unusual conditions, such as early indicators of a stressor or disease. Finally, any integrity breach to physical structure, such as fences, barns, storage areas, water and food supplies, as well as unusual impressions to physical security may indicate a potential agricultural threat [60-62].

Preventative measures within food and agriculture sectors include many of the elements of any sound security apparatus. For example, the collection of information and intelligence from all potential stakeholders (i.e. researchers, livestock and farm owners, buyers, veterinarians, etc.). Programs designed to seek out potential threats, their motivations, and modeling to forecast or predict targeted attacks would also be of benefit. The continued surveillance of crops and livestock, as well as monitoring and early detection programs that seek out and investigate emerging threats are also necessary elements of a well-designed security initiative. The industry requires continuous monitoring of livestock, crops, and food, and inoculation or vaccination to address specific diseases. Finally, it is necessary to maintain the same level of education and training, public awareness campaigns, and vigilance, as provided through existing treaties, conventions, protocols, and agreements, particularly counter proliferation and strategic efforts [63].

For example, risk assessment of crop security has been accomplished in Europe through efforts involving the development of candidate pathogen lists, "scenario-based investigation of potential agroterrorist acts," and design of risk-assessment schemes [64]. Early detection of exotic/foreign pathogens help establish containment, epidemiology, and treatment. Predictive modeling and forecasting of dispersion patterns helps avoid disasters when a disease is identified and it helps contain the effect to specific geographic regions. Likewise, for infected animals, depopulation and carcass disposal is a necessary protocol, and interstate or international agreements may include which prophylactics or vaccines are necessary, whether there will be any veterinary or pharmaceutical stockpiling, and the types of diplomatic, legal, economic, and political response needed [65-67].

Effective Programs involve collaborations, such as the Strategic Partnership Program Agro terrorism (SPPA) Initiative of the United States. The U.S. Food and Drug Administration, the Department of Homeland Security, the U.S. Department of Agriculture, and the Federal Bureau partner with industry and State volunteers to achieve objectives, such as validating or identifying sector-wide vulnerabilities and inform the Centers of Excellence and Sector-Specific Agencies, developing response and mitigation strategies, distributing information, and collaborating with other agencies (i.e. the Centers for Disease Control) and comporting to the Food Safety Modernization Act (FSMA) in identifying, quantifying, and prioritizing vulnerabilities. Likewise, the International Food Safety Authorities Network (INFOSAN), hosted by the WHO, enables effective international surveillance through information sharing of "real-time" information through the Global Outbreak Alert and Response (GOARN) network. The system promotes International Health Regulations reporting of any disease of importance to international public health, and not merely the three most serious diseases (cholera, plague, and yellow fever) [8,68].

The Australia Group is an example of an informal form of countries which collaborate on export and import controls so that chemical or biological weapons are not developed. The Chemical Weapons convention and the biological and Toxin Weapons Conventions are followed as extensively as possible [69,70]. At the moment, there are at least 69 participating countries, including the U.S., Australia, Canada, the Czech Republic, the European Union (N=41), France, Germany, Iceland, Japan, Mexico, New Zealand, Republic of Korea, Spain, Sweden, Switzerland, the Ukraine, and the United Kingdom.

Another example of the strategic purpose of disease eradication is the European Commission's design of a list of 50 candidate crop pathogens which represent high potential agro terrorism threats to the European agriculture and forest landscape. The EU project, "CropBioterror," kept confidential for security reasons, identifies nonindigenous, quarantine, and endemic pathogens "with specific characterizations, such as mycotoxinogenic ability, high potential for mutation and hybridization and records of highly pathogenic exotic strains." CropBioterror was among the EU funded projects related to Biopreparedness, Bioterrorism and Biosecurity, along with ASSRBCVUL, Biosafe, Biosafety-Europe, BIO3R, Corps, Impact, Inftrans, and VHF/VARIOLA-PCR [8,71,72].

Discussion

In a recent study of critical infrastructure resiliency involving Latin American Countries and the Caribbean, 42 percent of respondent countries (N=26) reported that they possessed a Critical Infrastructure Protection (CIP) strategy and that roles existed for policymaking, administration, and management of threats. Thirty-one percent had a CIP strategy adopted within the government sector, and 27 percent of the responding countries stated they had not adopted a CIP strategy, but the necessity of a CIP strategy was well-understood. Respondents reported secure production, storage and distribution strategies and partnerships, including communication and information-sharing. The significance of the information gleaned from this survey can be seen when reviewing the intelligence reports regarding the success upon which cybercriminals have permeated the government and industry within Argentina, for example. "Argentina is one of the countries with the highest cybercrime activity in the world (and when Colombia is considered) half of the phishing attacks in the world (can be accounted for, and include) fraud, targeted attacks, computer hacking, hacktivism, public and private information and identity theft, cyber terrorism and war, and military espionage" [73].

The survey was designed to evaluate private sector companies and their approach to security threats involving critical infrastructure (food and agriculture), how they deal with incidents, and how they manage other CIP considerations. The survey included questions related to the Food and Agriculture services sectors. It included outreach to all S. American countries, as well as the Dominican Republic, Costa Rica, Bahamas, Belize, Trinidad and Tobago, Barbados, and Mexico and Central America (Panama, Honduras, Guatemala, El Salvador, and Belize. One hundred thirty responses (13.2%) were received from the 933 contacts identified within the Latin American and Caribbean region). According to the FAO, several Latin American countries are among the highest global consumers of beef and veal, chicken, and pork and would likely suffer a critical infrastructure threat from any livestock disease [74,75].

The Global Terrorism Database provides detailed information on documented terrorist attacks, and includes biological, chemical, and many other weapons types, but it includes only 22 categorical descriptions for targets/victims, and food and water supply comprise one of the categories (http://www.start.umd.edu/gtd/). There is no category for livestock, so a reasonable conclusion can be reached that the GTD does not capture attacks on this part of agriculture. The only category which may capture the information is a Business target with "Farm/Ranch" as a subcategory, but still livestock are not listed as targets. In the GTD database, between 2012-2015, 3 biological and 31 chemical attacks were documented to involve poisoning in 7 specific cases involving attacks to food. The cases include poisonings of school-aged children attending schools in Afghanistan. On May 7th and 15th, 2012, over 250 Afghan students were hospitalized for poisoning. Schoolgirls in Afghanistan were poisoned on April 22, 2013, reportedly because they wanted to learn. Thirty-one police officers, including one who was fatally injured, were fed contaminated meat in the Faryab province, Afghanistan (November 20, 2012), while an assailant sold rat poison-laced meat to soldiers in Arauca, Colombia. Six were hospitalized, and one died of the meat poisoning. Between March of 2012, and April of 2013, as many as 53 police personnel were killed by Islamic terrorists, while 40 were injured with the serving of rat poison in food at police stations and academies. "Because no anti-crop agroterrorist act involving plant pathogens (excluding de facto human food poisoning) has ever been demonstrated, a prediction of the nature, the target crop, the pathogen introduced, and the perpetrator of 'the most likely act' targeting crops, is impossible" [8]. However, the effect of diseases on animals and livestock is well-documented and clearly observed and a security protocol would be remiss if it did not acknowledge the potential for an agroterrorist event.

Crop diseases have been deemed to rival military action, and the example of Bengal brown spot disease of rice in India, in 1942-1943, serves as an illustration of how the crop disease led to the starvation of 2.0 million people. The significance of this threat is that "the ongoing revolution in biotechnology and genetic engineering can extend the technical capabilities of anyone interested in developing biological weaponry, thereby increasing the threat. The genetic alteration of DNA compositions to create disease resistant and stronger, more resilient plants is an example of this view, and the previous research on deploying crop threats through balloons, feathers, spray aerosols, or even bombs, has greatly evolved into something more sinister [76].

Given the literature and case review of natural and human motivated outbreaks, it is sound to assume that the surveillance systems, the network of collaborations, and the knowledge of virulent pathogens gleaned through on-going scientific research, the greatest threat is not posed by potential agro terrorism targets, but by the aerial, waterborne, and the zoonotic effect of naturally-occurring and new genetic strains of evolving pathogens. The smuggling of wildlife and goods is also an issue because of the possibility of infectious disease that can spread and decimate livestock and plants. An outbreak of Exotic Newcastle Disease among poultry in the U.S. reportedly stemmed from smuggled game birds from Mexico. The disease resulted in eradication costs of approximately $168 million [77].

Double agents, pathogens capable of inflicting death in both animals and humans, are of significant terrorist concern. In 1979, an accidental release of anthrax spores from a research laboratory in the Soviet Union resulted in the deaths of 66 people and the infection of 77 others. The infected and deceased resided within 4 kilometers and downwind from the release site. Livestock also died, and the final death toll is estimated to have been between 200 and 1,000 people [78]. The many multinational efforts and conventions that exist between countries have led to increased international surveillance, better control measures, closer collaboration, additional research, and sharing of information and intelligence. However, new parasites and infectious diseases continue to emerge, or recur, and outbreaks continue despite prior effective control measures. The only two globally-eradicated viruses are smallpox and rinderpest [79]. The Disease Outbreaks Map and many state government health organizations, such as the United Nations, the World Health Organization, country specific organizations, and non-government organizations report public health outbreaks, many of which occur naturally, or through mishandling of plants and animals. During the month of February, 2017, for example, real-time outbreaks in humans have included H1N1 (India), American Swine Fever (Ukraine; Russia), Hantavirus (Texas, USA), Cholera (Zambia; Sudan), Lassa fever (Nigeria) [80].

The surveillance and reporting structure of effective programs can also be illustrated in the infrastructure of the United Nations. The Food and Agriculture Organization of the United Nations, in its Global Animal Disease Intelligence Report (2015), highlights livestock and zoonotic disease occurrences. Foot and Mouth Disease (FMD) remained a significant threat to many countries: Northern Africa (Algeria), East Asia (Republic of Korea), South Africa, and sub-Saharan Africa. "In Kazakhstan, a mass die-off of 152,336 Saiga antelopes… occurred over a two-week period in May 2015" [81]. As with a previous fatality of 12,000 Saiga in 2010, the Kazakhstan authorities reported to the OIE, that the causes are unknown, but may be due to Haemorrhagic septicaemia. The U.S. Department of Agriculture National Agricultural Library provides detailed information on many of the agents, including the microbes described by Kazakhstan. This virus is believed to have been introduced to the U.S. in 2002, and it affect aquatic life (fish) [82].

The OIE is the organization referenced by the World Trade Organization to develop standards relating to animal health and zoonosis. The OIE publishes the Terrestrial Animal Health Code and the Aquatic Animal Health Code as well as the Manual of Diagnostic Tests and Vaccines for Terrestrial Animals and the Manual of Diagnostic Tests for Aquatic Animals as international standards to improve worldwide animal health and ensure the sanitary safety of trades in terrestrial animals and aquatic animals and their products [83]. The World Organization for Animal Health has succeeded the Office International des Epizooties (OIE).

Currently, the OIE is comprised of 180 member countries, many who joined after the acute and viral disease known as Rinderpest, became epidemic within their region or food supply system. The disease affected ruminants, mostly zebu in Belgium, France, and Antwerp in 1924. The disease was eradicated from the world in 2011, but strains remain in research and science laboratories in several countries. Historically, Rinderpest was an economic scourge that affected Africa Asia, and Europe and it took the effort of the OIE and World Organization of Animal Health to eradicate it globally in 2011. Rinderpest is closely related to the viruses causing peste des petits in ruminants, canine distemper, and measles. It is shed in nasal and ocular secretions and may be transmitted during incubation. Close or direct contact between animals may result in transmission, but the virus is fragile, inactivating within 12 hours of exposure to heat and light. The incubation period is 3-15 days. Morbidity is about 100 percent, and mortality up to 90 percent. Rinderpest is not zoonosis. The worldwide eradication of Foot and Mouth Disease is the next aim of the OIE [79,80].

While Avian Influenza (H5N1; HPAI) are characterized as medium risk, zoonotic avian influenza outbreaks were reported in Africa and Asia, with new incursions into Africa, the Near East and Eastern Europe to Central Asia (Russian Federation, Kazakhstan, Turkey, Gaza Strip, Israel, and the Islamic Republic of Iran). The outbreaks were reportedly of East Asia origin. In Western Africa, outbreaks occurred in Cote d'Ivoire, Ghana and Niger. Nigeria reported new outbreaks affecting poultry, and as a result, it exterminated 1.4 million birds. Egypt reported increases in H1N1/H5N1 in poultry and humans, resulting in the deaths of 27 people during the first six months of 2015. Other countries experiencing outbreaks include Israel, Islamic Republic of Iran, and Eastern-South Eastern Asia (Bhutan, China, India, Indonesia, and Viet Nam). Other Avian Influenza outbreaks were reported during 2015 in China (H7N9; LPAI; n=32), the United States (H5N8/HPAI; n=21-), Canada (n=3), Mexico (n=3), and Egypt [84,85].

Plant pathogens continue to be sources of concern because weather disperses them through natural aerial means. “Some of the most striking and extreme consequences of rapid, long-distance aerial dispersal involve pathogens of crop plants, such as long-distance dispersal of fungal spores by… (wind, spreading) plant diseases across and even between continents and reestablishing diseases in areas where host plants are seasonally absent” [86]. While some of these aerial dispersals may cause extreme consequences, a lower probability exists that plants, viruses and fungal pathogens may also infect humans. The aerial dispersal cases include spores carried on clothing, causing yellow wheat rust in Australia around 1979, originating in Europe, and later spreading to New Zealand in 1980 by wind dispersal of uredospores from Eastern Australia. The map includes references to extinction-recolonization cycles of airborne spores, some of which may be carried by travelers on their clothing [87].

Conclusion

Attacks against people and the infrastructure of their societies through the release of pathogens directed at food and agriculture are a compelling threat because food products are essential to sustain life. The nature of the pathogens, the manner of dissemination, the efficacy of surveillance systems, and the competency of first responders serve as critical indicators to the lethality of the attacks. Some actions may inflict mass effect, and not necessarily mass casualties. Therefore, “the key to the effective defense against an attack using biological agents is to have in place highly functioning public health surveillance and education systems and an appropriate healthcare infrastructure to mitigate the consequences in the event that an attack takes place” [88]. The global food supply chain inherently possesses substantial concerns. Several include the effect of global warming and inclement weather, water conditions, aquaculture, and its effect on food and livestock production, population growth and a demand for more food and animal products. Also, renewable agriculture and food systems, increasing homogeneity of world food supplies, fertilizer efficacy, increasing rural development, greenhouse gas emissions, and the protection of valuable ecosystems represent some of the greatest challenges. To compound this complex system, there is a growing threat of unorthodox terrorist acts and disrupting any part of the food supply chain may bring a devastating economic problem to a global region. With the growth in global population and the significance of food and agricultural needs, greater attention must be placed on the threats to crops, livestock, and their byproducts within our food supply chain. Thus, effective surveillance systems, improved knowledge of pathogens, and efficient responses are needed to protect the food sources which sustain our lives.

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