Entomological Terrorism: A Tactic in Asymmetrical Warfare

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ABSTRACT

The current operational environment presents military forces with enemies that use unconventional warfare to achieve their goals. Although the US government has dedicated significant resources to address threats of bioterrorism, the adaptive nature of our adversaries necessitates additional emphasis on bioterrorism awareness among military health professionals. This article provides an overview of 3 categories of entomological terrorism and examples from each category with a risk assessment.

Historically, most US wartime casualties have been from disease and nonbattle injuries. If proper precautions are not taken, diseases like malaria, leishmaniasis, giardiasis, and botulism can have a detrimental impact on military personnel, their units, and their missions. Preventive medicine and public health personnel at all levels must remain vigilant during deployments to protect Soldiers from contracting food, water, and vector-borne diseases. The current operational environment, with insurgents using unconventional, indirect attacks against US forces, has caused the military to prepare for a wide array of enemy tactics. Improvised explosive devices (IEDs), vehicle-borne IEDs, snipers, and suicide bombers have all been used against military personnel, local security forces, and various local nationals in the Iraq and Afghanistan theaters. Another unconventional tactic that could be used by our nation's enemies is the use of biological terrorism, also known as bioterrorism.

Bioterrorism is defined as the deliberate release of viruses, bacteria, or other pathogens to cause illness or death in people, animals, or plants.[1] It should be noted that this definition excludes macrobiotic organisms, such as insects, which have been used to attack humans and agriculture. We would expand the Centers for Disease Control and Prevention definition to recognize the history and future of bioterrorism as including all living organisms. Insects have the potential to act as effective instruments for bioterrorism. This article will specifically address the threat posed to both the US civilian population and military personnel from entomological terrorism. Entomological terrorism can be organized into 3 major categories: the use of insects as weapons of direct attacks, as agents of agroterrorism, and as disease vectors.[2] We would note that these categories are not mutually exclusive. For example, a plant disease vector could be an agent of agroterrorism.

Composite risk management (CRM) is the Army's primary decision-making process to identify hazards, reduce risk, and prevent both accidental and tactical loss.[3] The US Army Center for Health Promotion and Preventive Medicine *Technical Guide 288*,[4] used by preventive medicine personnel, applies the CRM concept to vector-borne disease threats encountered by military personnel. Risk management in the Army, regardless of what is being assessed, ultimately seeks to preserve the fighting force for future operations. *Technical Guide 288* provides the framework to assess entomological hazards faced by military personnel, but was not intended to serve as a guide for analyzing entomological terrorist threats to our nation. The tactics used by our adversaries in overseas contingency operations have in many instances focused on targets other than military personnel. Unconventional strategies used by our enemies have included terrorist attacks to our nation on September 11, 2001, our international embassies, and our allies to include the Iraq and Afghan governments. Bioterrorism, including entomological terrorism, can instill fear in a society, devastate economies, and cause disease throughout a populace. Entomological threats should be further evaluated with considerations given to their potential use in attacks by our nation's enemies. Applying the Army's CRM and using *Technical Guide 288* as a

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14. ABSTRACT
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guide, examples of each form of entomological terrorism (direct attacks, agroterrorism, and disease vectors) are assessed in this article to illustrate their potential threat to the health of our nation's military, economy, and society.

Direct Attacks

Stinging insects were used for millennia in conflicts as a means of defending fortifications or routing enemies from entrenched positions.[2] It may appear that modern weapons have eliminated the need to conscript insects for such purposes, but such tactics were used by the Vietcong against US troops in Vietnam,[2] and their use by terrorists in a direct attack is not altogether improbable. More likely, military personnel will have natural exposures to biting, stinging, or toxic insects as part of military deployments in less sheltered conditions and unfamiliar environments.

According to *Technical Guide 288*:

> In addition to vector-borne and zoonotic disease, entomological hazards during deployment also include those hazards associated with biting and stinging arthropods, animals, poisonous plants, and pesticide exposure. Biting and stinging arthropods can degrade mission readiness and combat effectiveness even though they are relatively free of vector-borne disease. These arthropods can cause casualties from secondary infections and even death from allergic reactions to their venom. Annoyance from high populations of pests, itching bites, and loss of sleep can also reduce morale.[4(p2)]

One documented threat to military personnel that could be used in a direct attack or encountered in the environment is the *Paederus* beetle.[5] *Paederus* is a genus of rove beetles (family Staphylinidae) and are found in the Middle East and the Asian subcontinent. Most species are slender, about 7 mm to 13 mm long, and are distinctly colored with black heads, orange bodies, black abdominal tips, and metallic blue or green elytra[5] (Figure 1). A string of suppurating sores appears when someone brushes away a beetle and inadvertently smears the insect and the toxin, pederin, across the skin. Less than a hundred-thousandth of a gram of this chemical can cause festering lesions.[2] Intense pain and temporary blindness have been reported when pederin is introduced into the eyes. These sores, although not fatal, may result in lost duty time.[6] Ingestion of the beetle leads to severe and even deadly internal damage. Pederin is lethal if injected into the bloodstream.[2]

Military personnel currently conduct operations in environments throughout Iraq that support *Paederus* beetle populations. The entomological hazard assessment[4] for *Paederus* beetles in these areas of Iraq was evaluated based on the severity and probability of exposure. *Paederus* beetles pose a "marginal" hazard to military personnel and the probability of receiving an injury by these beetles would be "occasional," therefore, the risk estimate for this entomological threat is "moderate" in areas with *Paederus* beetle populations. Military personnel can reduce the risk of the typical method of exposure to these beetles by applying an indoor residual spray (permethrin) in tents (D. A. Strickman, PhD, oral communication, January 2010), not working or resting under bright lights during May through July, properly wearing uniforms, and using window screens to help prevent *Paederus* beetles and other insects from traveling toward light sources indoors.[6]

The stings and bites of insects and arthropods are one threat the US Army should be able to manage effectively. Since its adoption, the Geneva Protocol of 1925[7] has prevented most nations from using chemical or biological weapons. The use of insects to vector pathogens is also prohibited under the Protocol. However, terrorists do not bind themselves to such protocols and could possibly employ biological weapons against the United States. The difficulty in

Figure 1: Dorsal and Ventral view of a *Paederus* beetle. Image courtesy of US Army Public Health Command (Provisional).[6]

the control of biological pathogens indicates that terrorists would probably use them at a location remote from their own territory (ie, against civilians residing in the United States). On the other hand, it is evident that terrorists are willing to both kill their countrymen and to die in attacks against US forces, which suggests that there are no places entirely safe from biological weapons. The 2 main entomological terrorism threats to the United States at home are agroterrorism and vector-borne disease threats.

AGROTERRORISM

Agroterrorism is defined as:

> the deliberate introduction of an animal or plant disease as well as damage to crops and livestock with the goal of generating fear, causing economic losses, and/or undermining social stability.[8]

Insects can be agents of agroterrorism as they can vector plant or animal pathogens or directly damage economically important crops and livestock. Table 1 identifies plant pests of significant concern in terms of bioterrorist potential. Many insects that are problematic to agriculture are invasive species. Invasive species can be defined as species that have a demonstrable ecological or economic impact and that have become established in a region outside of their native range.[10] Insects that become invasive to the United States can arrive in various ways, including:

- Accidental introductions of a species by global travel or trade
- Species originally released for agricultural or economic gains that later became problematic pests
- Species released in an act of bioterrorism against our nation

Agriculture and livestock remain a vital part of the economic stability of the United States. Although farming employs less than 2% of the country's workforce, 16% of the workforce is involved in the food and fiber sector, ranging from farmers and input suppliers to processors, shippers, grocers, and restauranteurs.[11] The US produces and exports a large share of the world's grain. In 2003, the US share of world production was 42% for corn, 35% for soybeans, and 12% for wheat. Of global exports, the US accounted for 65% for corn, 40% for soybeans, and 32% for wheat.[12]

Economic losses from an agroterrorist incident could have the following effects:

- Value losses in terms of lost production, cost of destroying diseased animals or products, and cost of containment (drugs, diagnostics, pesticides, and veterinary services).[8]
- The imposition of trade restrictions on US exports by foreign nations to prevent the disease or pest from spreading.
- Damage to the US economy as tourism and agriculturally dependent businesses suffer.
- State and federal governments burdened by the significant costs associated with disease or pest eradication, containment efforts, and compensation to farmers for their losses.

The Mediterranean fruit fly (*Ceratitis capitata* Wiedemann), commonly known as the Medfly (Figure 2), is a possible entomological agent that could be used against the United States for the purposes of agroterrorism. The species is found in Hawaii, but is not established on the US mainland . The larvae of this fly eat a wide variety of plants, including avocados, coffee, olives, tomatoes, bananas, citrus, mangos, and peaches.[2] If Medflies were established in California, a total quarantine of California fruits, both nationally and internationally, would result in the loss of 132,000 jobs and $13.4 billion.[13]

Medflies played the central role in a relatively recent entomological threat faced by our nation's citrus growers. In 1989, an ecoterrorist group known as the "Breeders" threatened to release Medflies in California if the state did not stop its pesticide spraying program. The State of California was spraying pesticides, ironically, to remove Medflies that had appeared in the Los Angeles area.[2]

Applying the criteria of *Technical Guide 288*, the severity of damage caused by Medflies to the United States would be "critical" and the probability of this pest occurring and becoming established is "likely," therefore the risk assessment for this pest is "high." There are mechanical, cultural, biological, and chemical control measures that can be used to control and eliminate Medflies, however, preventing the Medfly from establishing itself on the mainland would be less expensive than control measures.

Table 1. Exotic plant pests of greatest risk.[a]

Pest Common Name(s): Scientific Name	Expected Range	Ecological Suitability[b]	Survey Difficulty[c]	Taxonomic Difficulty[d]	Primary Damage	Potential Economic Risk	Potential Environmental Impact	Potential for Establishment
Japanese wax scale: *Ceroplastes japonicas*	67% US (eastern and western states)	High	High	Medium	Ornamentals Fruits	High	High	High
Metallic beetle, Oak splendor beetle: *Agrilus biguttatus*	67% US (eastern and western states)	High	High	Medium	Oak Beech Chestnut	High	High	High
Rice cutworm, Cotton leafworm: *Spodoptera litura*	67% US (eastern and western states)	High	Medium	High	Vegetables Field crops	High	(Low)	High
Silvery moth: *Autographa gamma*	50% US (eastern and parts of western states)	High	Medium	High	Vegetables Field Crops Greenhouses	High	(Low)	High
Egyptian cotton leafworm: *Spodoptera littoralis*	67% US (eastern and western states)	High	Medium	High	Cotton Vegetables Ornamentals Forages	High	(High)	Medium-High
Passionvine mealybug: *Planococcus minor*	67% US (western and mid-western states)	Medium	High	Medium	Many crops	High	High	High
Light brown apple moth: *Epiphyas postvittana*	90% US	High	Medium	High	Ornamentals Fruits	High	(Low)	Medium
Khapra beetle: *Trogoderma granarium*	67% US (eastern and western states)	High	Low	High	Stored grain	High	Medium	High
Arrowhead scale: *Unaspis yanonensis*	33% US (eastern, portions of midwest and California)	Medium	High	Medium	Citrus Vegetables Trees	High	Medium	High
Siberian silk moth: *Dendrolimus superans*	80% US (except parts of western states)	High	Low	Medium-Low	Conifers	High	High	High
Ambrosia beetle: *Platypus quercivorus*	33% US (eastern states and Oregon)	Medium	Medium	Medium	Oak Chestnut	High	High	Medium
Summer fruit tortrix moth: *Adoxophyes orana*	25% US (eastern states and Oregon)	Medium	Low	Medium	Fruit	High	High	High
Pink gypsy moth: *Lymantria Mathura*	50% US (eastern and parts of western states)	Medium	Low	Low	Fruit crops Forests	High	High	Medium

[a] Data adapted from the USDA Animal and Plant Health Inspection Service Mini Pest Risk Assessments.[9] There is no comprehensive summary of agricultural threats, although these pests are representative of the agents that could be used for bioterrorism. The ratings of risk presume that each of the listed categories is of equal weight. The qualitative assessments were converted into scores and summed, such that "high" = 3, "medium" = 2; "low" = 1 (in all columns "high" is associated with a quality favorable for bioterrorism). Because potential environmental impact was not explicitly listed for all species, this category was not included in the summed risk score (the authors' estimates for this assessment, based on the USDA descriptions, are shown in parentheses). When totaled scores yielded a tie, potential environmental impact and expected range were used.

[b] Ecological suitability concerns whether the pest's life history accords with climates, soils, and host plants in the United States and the extent to which these ecological conditions are available.

[c] Survey difficulty addresses whether the United States has methods to readily detect the pest (eg, pheromone traps and sampling methodologies) and the extent to which the pest and its damage remain cryptic.

[d] Taxonomic difficulty reflects the ease with which the pest can be differentiated from native insects, the variability of the pest across its life stages, and the availability of supporting materials (eg, taxonomic keys).

[e] Species evaluated in the "mini pest risk assessments" representing lower threats and not included in this table are (in alphabetic order by common name): Chestnut weevil, *Curculio elephas*; European grape vine moth or Grape berry moth, *Lobesia botrana*; False codling moth, *Thaumatotibia leucotreta*; Fruit piercing moth, *Eudocima fullonia*; Giant woodwasp, *Urocerus gigas*; Old World bollworm, *Helicoverpa armigera*; Soft wax scale, *Ceroplastes destructor*

There are ways to mitigate the threat of agroterrorism to our nation. Monitoring, containment, and continued research will help prevent a terrorist event. The following are several suggestions to stop agroterrorism:

- Increase funding for research and eradication programs of invasive species present in the United States.
- Establish or continue monitoring programs for invasive species such as the Medfly, the Emerald Ash Borer (*Agrilus planipennis* Fairmaire) (monitoring in adjacent states that have not previously had this pest), and the Khapra beetle (*Trogoderma granarium* Everts), a grain and stored products pest.
- Ensure agencies responsible for monitoring trade and security threats to the United States are trained to identify entomological hazards and deter their entry to the United States. Possible participating agencies include the Food and Drug Administration, Food Safety and Inspection Service, and US Customs and Border Protection. The agency primarily responsible for this function is the US Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS).

Figure 2. Adult Mediterranean fruit fly. Image courtesy of US Department of Agriculture (http://www.ars.usda.gov/is/graphics/photos/jun00/k8898-2.jpg).

DISEASE VECTORS

An intentional release of a vector-borne disease by adversaries of the United States is a realistic threat to our nation. Table 2 provides a list of arthropod-transmitted diseases that could be delivered in a terrorist act that pose significant risks to plant, animal, and human health. The adverse effects caused by the introduction of certain arthropod-vectored pathogens to the United States, whether accidental or intentional, could ultimately result in illness and death from disease or devastation of the economy. This could be compounded if the introduced pathogen became established within our nation's borders and persisted, despite control and eradication efforts. Engineering new strains of viruses would require resources that typical insurgent groups do not possess at present, but many naturally occurring pathogens do exist that would need minimal effort to develop into biological weapons. Furthermore, the delivery of these diseases by terrorists to US soil could be simple and leave little to no evidence of the attack.

Rift Valley fever is an excellent example of a disease that would require little effort to deliver to the United States, and could have devastating effects on the nation's public health and livestock industry. Rift Valley fever (RVF) is caused by a virus in the family Bunyaviridae and occurs in various regions of sub-Saharan Africa and Madagascar.[19] Recent outbreaks in the Arabian peninsula, the first reported cases outside the African continent, have raised concerns that the disease could extend into Asia and Europe[20] (Figure 3). Numerous mosquito species transmit the virus that causes RVF, including those inhabiting North America and the United States.[21] The virus can be passed to an infected mosquito's offspring via transovarial transmission, thus enabling its persistence and maintenance in the environment through long stretches of dry conditions. Eggs infected with the virus can lay dormant until rains arrive when they will then hatch, develop in the larval and pupal stages, and emerge as disease-carrying adults. The public health and economic impacts of a RVF outbreak in the US could far exceed anything experienced by recent West Nile virus events.[2,22] Although these diseases spread in much the same manner, both the infection rate and proportion of those exhibiting severe symptoms are vastly higher in RVF.

The intentional introduction of RVF through infected mosquitoes, humans, and/or livestock represents a

serious threat to both our military and civilian populations, whether delivered by a terrorist or through accidental introduction. The RVF virus is transmitted to humans by the bite of an infected mosquito or through contact with animals/meat that are infected. The mild form of RVF observed in most human infection manifests itself in the form of flu-like symptoms. The more severe form of the disease appears in one of 3 syndromes: ocular disease, meningoencephalitis, or haemorrhagic fever. Using RVF's approximate case fatality rate of 1%,[19] the analysis of a hypothetical attack allows us to better understand the implications of such an outbreak. If a small community with a population of just 10,000 people experienced a 10% RVF attack rate, the results would overwhelm the local health care infrastructure. Approximately 1,000 cases of the disease would require medical attention, with approximately 10 people ultimately dying from debilitating symptoms. In this age of constant news streams from cable networks (ie, CNN, MSNBC, Fox News), word of even a small outbreak of RVF would make headlines.

The absence of human cases occurring in a RVF bioterrorist attack would not equate to failure for our adversaries. An intentional release of RVF would also be a form of agroterrorism, for the livestock losses this disease can cause could cripple a large part of our national economy. Cattle, sheep, dogs, and rodents are among the many animals susceptible to RVF. Outbreaks of RVF have been characterized by high attack rates in livestock, with 30% mortality and abortion rates approaching 100%.[23] Corrie Brown, an animal infectious disease specialist who supervised the pathology section of USDA's Plum Island Animal Disease Center in New York, contends that if an outbreak occurred in the United States, domestic beef exports would shut down.[2,24] This impact on the beef industry would result in a $3 billion ($10^9$) loss to the economy.[2,24]

The composite risk assessment for the threat of RVF being delivered in an act of terrorism was estimated to be a "high" due to its "critical" severity and its probability occurrence "likely."[4]

Control measures that can mitigate the risk of RVF include:

- Continue mosquito surveillance programs to both monitor various pathogen infection rates (ie, West Nile and Eastern Equine Encephalitis) in vector populations as well as maintain preparedness in the event of an RVF or other mosquito-borne disease outbreak.
- Monitor conditions suitable for RVF outbreaks (eg, regional flooding, hurricanes) to focus mosquito control and surveillance efforts.

Table 2. Arthropod-transmitted exotic diseases of potentially significant risk to plant, animal, and human health.[a]

Disease	Vector(s)	Pathogen	Host(s)
Chikungunya	Mosquitoes	Virus	Humans[b]
Yellow fever	Mosquitoes	Virus	Humans[c]
Japanese encephalitis	Mosquitoes	Virus	Humans, pigs, birds
Rift Valley fever	Mosquitoes	Virus	Humans, livestock, birds
Lumpy skin	Mosquitoes and other flies	Virus	Cattle[d]
African horse sickness	Biting midges	Virus	Horses
Russian spring-summer encephalitis	Ticks	Virus	Humans[e]
Crimean-Congo hemorrhagic fever	Ticks	Virus	Humans[f]
Cattle tick fever	Ticks	Virus	Cattle
African swine fever	Ticks	Virus	Pigs
New World screwworm	Adult screwworms flies	NA	Mammalian livestock[g]
Tomato yellow leaf curl	Whiteflies	Virus	Tomatoes[h]
Citrus chlorotic dwarf	Whiteflies	Virus	Citrus
Citrus variegated chlorosis	Leafhoppers	Virus	Citrus
Lime witches' broom	Leafhoppers	Phytoplasma	Lime
Pierce's disease	Leafhoppers	Bacterium	Grapes
Potato wilt or brown rot	Leafhoppers, beetles, aphids	Bacterium	Potatoes[i]
Citrus greening	Psyllids	Bacterium	Citrus

[a] Data sources: USDA,[9] Frazier and Richardson,[14] Geissler,[15] Pelzel,[16] Wilson et al,[17] and World Health Organization.[18]

[b] Various nonhuman animals can serve as reservoirs.

[c] Other primates can serve as reservoirs.

[d] Insect vectors are highly suspected but have not been specifically identified.

[e] Small mammals can serve as reservoirs.

[f] Small mammals and domestic livestock can serve as reservoirs.

[g] Infestations of screwworms are not a disease in the classic sense but share many important commonalities with pathogenic infections.

[h] Localized infections have been found in California, but the disease is not yet established.

[i] Insect vectors are highly suspected based on experiments with closely related diseases but have not been specifically identified.

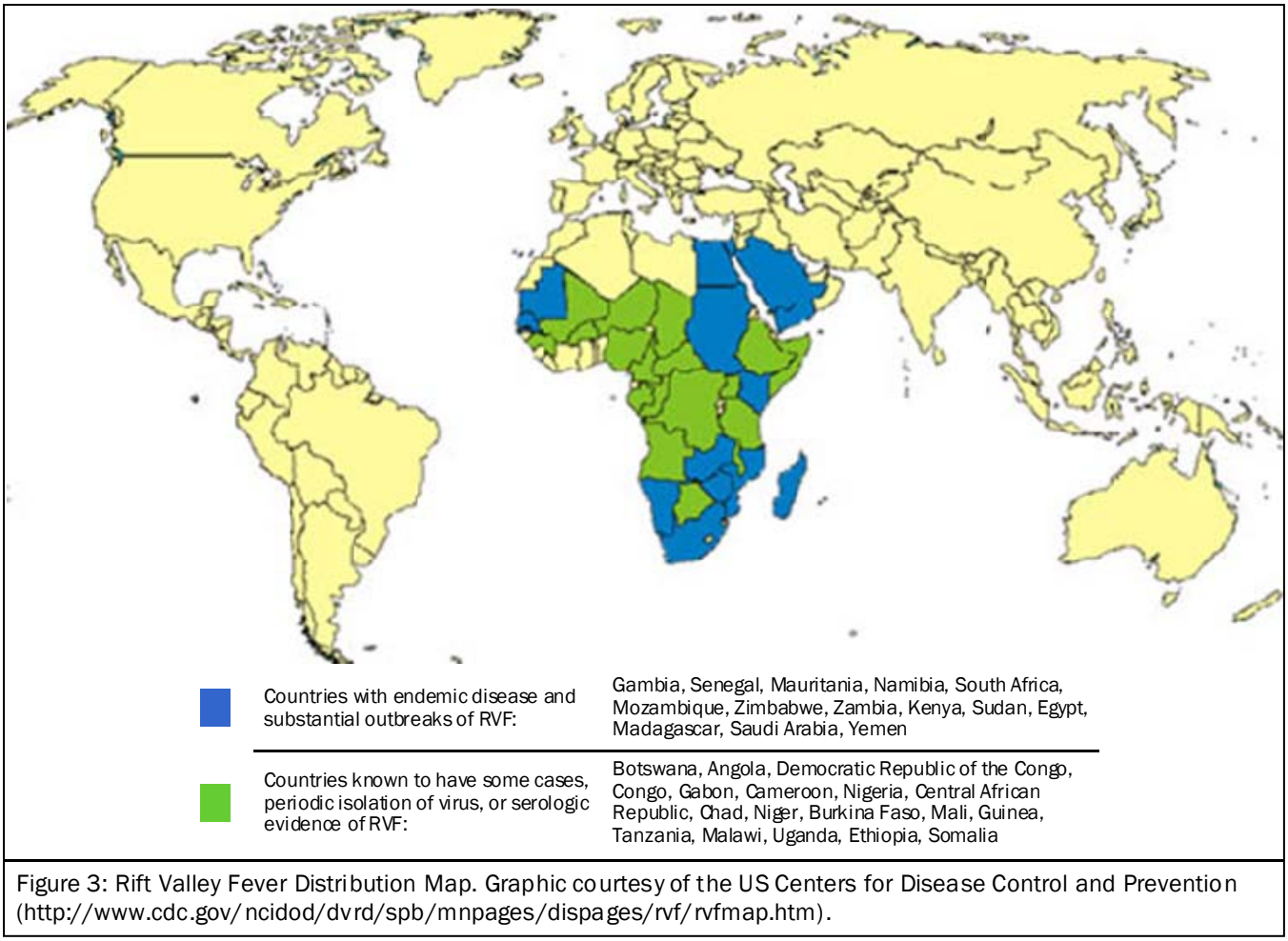

Figure 3: Rift Valley Fever Distribution Map. Graphic courtesy of the US Centers for Disease Control and Prevention (http://www.cdc.gov/ncidod/dvrd/spb/mnpages/dispages/rvf/rvfmap.htm).

- Develop and rehearse RVF outbreak response plans to be implemented by the Department of Homeland Security (DHS) and Federal Emergency Management Agency.
- Ensure RVF vaccine could be readily available for the public in the event of an outbreak. An inactivated vaccine has been developed for human use. However, this vaccine is not licensed and is not commercially available. It has been used experimentally to protect veterinary and laboratory personnel at high risk of exposure to RVF. Other candidate vaccines are under investigation.[20]
- Institute a mobile, federal vector control force that could respond to such emergencies.

Various state, federal, and international entities have recognized the threat of RVF and have implemented some of the above control measures. Contingency planning, predictive disease modeling, and outbreak response exercises represent some of the recent developments to combat RVF threats in both endemic and potentially exposed geographic regions. The Food and Agriculture Organization (FAO) of the United Nations is just one of the international agencies providing guidelines for development of RVF contingency plans.[25] The FAO provides vital information for animal and human health authorities of individual countries by specifying RVF details regarding risk analysis, prevention strategies, early warning signs, forecasting, and control strategies.

Weather patterns and anomalies have been used recently to model and predict RVF outbreaks. In Africa, outbreaks of RVF are integrally tied to widespread elevated rainfall, and the subsequent flooding and increase in vegetation.[26] Risk mapping using climate and normalized difference vegetation index data led to the first prediction of an RVF outbreak from December 2006 to May 2007.[27] The predicted RVF occurrence provided a warning period of 2 to 6 weeks that facilitated response and mitigation

activities. The outbreak that subsequently occurred validated the utilization of risk mapping models to predict future RVF events.

While contingency plans and outbreak predictions provide the logistical framework and science needed, rehearsing the execution of epidemic disease scenarios, with all responding agencies involved, ultimately provides the best gauge of response preparedness. In November 2008, Paul Gibbs, PhD, from the College of Veterinary Medicine at the University of Florida supervised a multiagency test of Florida's response to a hypothetical introduction of RVF (http://www.flsart.org/rvf/index.htm). Incorporating various state and federal participants, including the DHS, the Federal Bureau of Investigation, and the USDA, the exercise trained major stakeholders to collaborate in response to an introduction of RVF virus into Florida. In light of the original event's success, 2 additional RVF exercises were planned and conducted in Puerto Rico and the Virgin Islands by Dr Gibbs and Dana McDaniel, DVM, in 2010 (Dr McDaniel, oral communication, March 2010).

The control measures discussed could reduce the impact from an RVF outbreak, whether the virus is delivered by terrorists or arrives by accident. Without further scientific advances in RVF forecasting, vaccine development, vector control, and diagnostic capabilities, it may be unrealistic to expect to attain the necessary resources required to build and maintain comprehensive control measures to eliminate the threat to our nation of RVF and similar vector-borne diseases. We conclude that the residual risk associated with the threat of RVF, and other vector-borne diseases, remains "high."

DISCUSSION

Entomological terrorism, regardless of its form, is a current and future threat faced by the United States. The estimated risks of the threats outlined in this article are speculative, however, it would be difficult to argue that the hazards associated with entomological terrorism are negligible. The US government has long recognized the consequences of biological warfare. The federal agencies conducting research and development on vector-borne diseases and crop pests include, but are not limited to the following:

- DHS: National Center for Foreign Animal and Zoonotic Disease Defense, and US Customs and Border Protection
- US Army Medical Research Institute of Infectious Disease (USAMRIID)
- Walter Reed Army Institute of Research
- USDA–Agricultural Research Service (ARS) and Animal and Plant Health Inspection Service

Additionally, some local abatement districts, a few state governments (ie, Florida, California), and numerous universities have also made significant contributions to research on vector-borne infectious diseases.

Merely studying the biology of a disease does not prepare us for response to an actual outbreak. Many aspects of an appropriate response to an entomological emergency still must be addressed, including:

- Is the pest management community prepared for an outbreak with the necessary equipment and knowledge to implement control techniques?
- Can pest management resources be quickly consolidated, mobilized, and deployed to outbreak locations?
- Are emergency organizations prepared with individual response plans for specific entomological threats, especially those posing high risk?

Accidental introductions of invasive arthropod species have a higher likelihood of occurring than intentional deliveries through terroristic plots. Military personnel moving to and from forward deployed environments can do their part in preventing the introduction of invasive species by thoroughly inspecting cargo transported by military transportation vehicles and by conducting retrograde washdowns of vehicles and equipment after a deployment.[28] The importance of preventing invasive species is illustrated by the costs currently incurred by these species in the United States. Damage caused by invasive species currently in the United States is estimated at $120 billion to $138 billion each year.[29] Crop losses and control costs due to invasive insects and pathogens were estimated at $25 billion in 2005.[29] There are approximately 500 invasive insect and mite species in crops and an estimated 20,000 species of microbes, including introduced plant pathogens, that have invaded the United States thus far.[29] Additional invasive species

would only compound the problem and costs caused by these pests.

Even with proper systems and technological advances in place to prevent attacks or mitigate the effects of disasters, the United States still faces a deficiency in the number of trained, qualified healthcare professionals. A large portion of the healthcare workforce (including public health professionals, clinicians, and related healthcare fields) in the United States is approaching retirement age.[30] Health professionals are not being trained at a rate needed to fill the loss of retirees.[30] Federal (including the US Army) and state agencies responsible for emergency preparedness and response will soon face personnel challenges requiring additional efforts to educate, train, and retain such public health professionals. A terrorist attack, especially with a biological weapon, would be more devastating if the medical infrastructure is poorly prepared, staffed, and funded.

CONCLUSION

Vector-borne diseases are a current threat because of the self-perpetuating capabilities and delayed morbidity and mortality following exposure or infection.[31] Most disease causing organisms used as biological weapons, particularly the zoonoses, can be delivered to a target population without risk of immediate detection.[31] This article illustrates that insects and other arthropods can be used by an enemy to attack US military personnel and civilians. Some recommendations on how to mitigate the specific threats given (ie, *Paederus* beetles, Medfly, Rift Valley fever) were presented, however, all military personnel can mitigate vector-borne disease threats by taking relatively simple actions.

- Deploying Soldiers and DoD personnel should practice operational risk management (ORM) for infectious diseases. Excellent resources for understanding and following ORM are *Technical Guide 288*,[4] as well as the website for the National Center for Medical Intelligence (http://www.phsource.us/PH/MI/index.htm).
- Personal Protective Measures should be implemented when training within the United States and when deploying outside the country. Treating uniforms with permethrin, or purchasing uniforms that are pretreated with permethrin, as well as using N,N-diethyl-3-methylbenzamide (deet) on exposed skin can reduce the likelihood of contracting mosquito- or tick-borne diseases during field training. The use of personal protective measures will not only help protect the individual from a new emerging vector-borne disease like RVF, but also prevent Soldiers from contracting Rocky Mountain spotted fever, Lyme disease, West Nile virus, Ehrlichiosis, and other vector-borne diseases present in the United States.
- Military personnel conducting food and water vulnerability assessments[32] or retrograde operations are critical players in security by helping protect food and water from exposure to biological agents and by preventing them, including vectors and invasive species, from entering the country.

Invasive pests and the diseases they may carry represent a threat that is magnified when terrorism is involved. The research conducted by academic institutions, a host of federal agencies (eg, USDA-ARS) and the US military (eg, USAMRIID), coupled with entities capable of organizing emergency response activities (eg, DHS, Federal Emergency Management Agency, state and local authorities), provide the critical framework needed to address the entomological threats we face. It would be ideal to provide a definitive countermeasure to entomological terrorism, however, this may be unfeasible due to the financial and logistical challenges involved. The most critical countermeasure to entomological terrorism is the same for any form of terrorism—vigilance by the US military, government agencies, citizens, and our allies.[31]

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