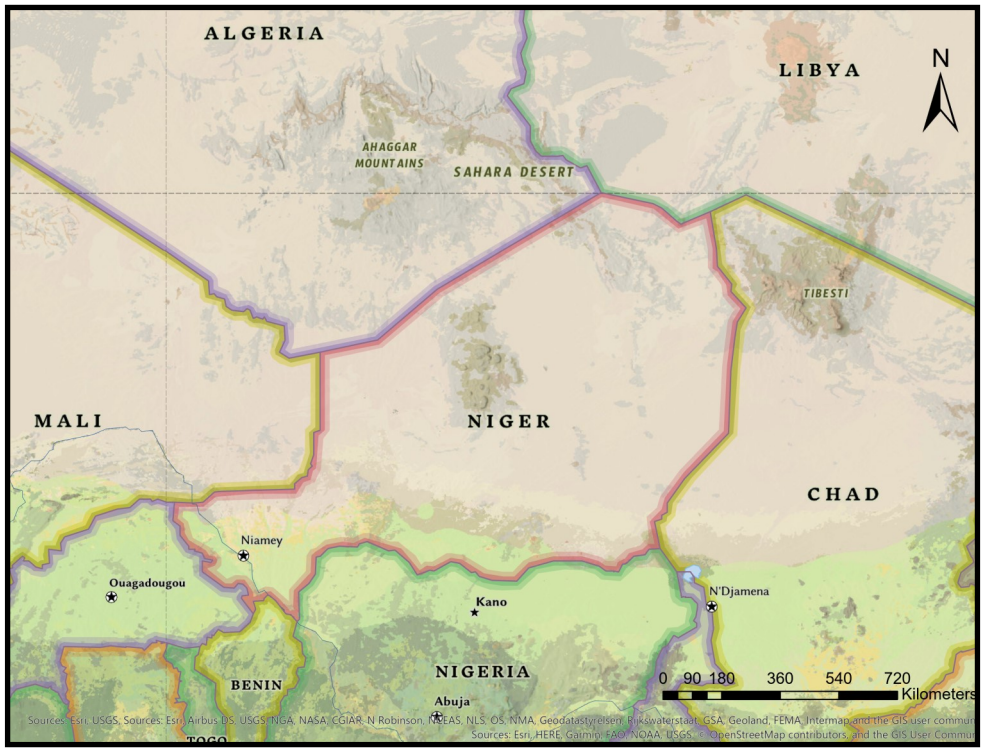
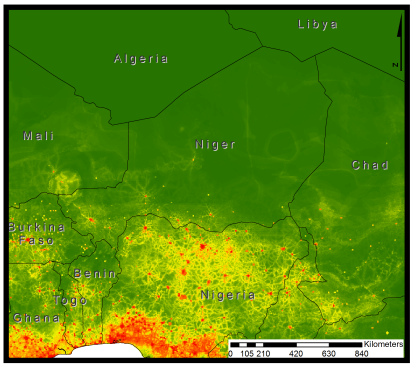
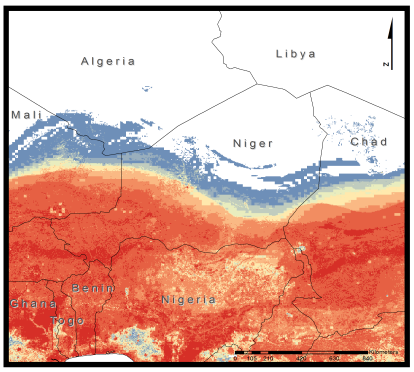
Vector Hazard Report:

Niger







Notes on the arthropod-borne disease threats, vector species ecology profiles and recommendations for surveillance and control.

WRAIR
Walter Reed Army Institute of Research
Soldier Health • World Health

WRBU

Preface

This product was co-produced by the Armed Forces Pest Management Board (AFPMB) and the Walter Reed Army Institute of Research, Walter Reed Biosystematics Unit (WRAIR-WRBU)

This document provides summarized information on the vectors and vector-borne diseases reported from Niger as of November, 2019. Information related to the identification, distribution, medical importance, control and surveillance of vector species are included. For updated information on the current hazards known from Niger, please use the near-real time hazard assessment links on page 3. Each page of this document is also hyperlinked via the table of contents to allow easy navigation and access to information most relevant to the reader. This report contains background information including a country overview, climate summary and host demographics**.** View the Vector Hazard Report Quick Guide pages for real-time threat assessment resources, quick navigation to vector-borne disease threats in Niger and resources for vector identification and monitoring insecticide resistance for updated information about current outbreaks and regional climate. Detailed bionomics data for each vector species is available on the vector species ecology profile pages for mosquitoes and ticks.

The target audience for this document are commanders, medical planners, preventive medicine personnel, and particularly medical entomologists.

For each vector-borne disease threat included in the report the following information is provided:

- **Disease Background**
- **Military Impact and Historical Perspective**
- **Transmission Cycle**
- **Additional Resources**

For each vector species threat included in this report, the following information is provided:

- **Current Taxonomy**
- **Bionomics**
- **Medical Importance**
- **Identification Tools**
- **Surveillance and Control Strategies**
- **Additional Resources**

Vector Hazard Report Quick Guide: Niger

Real-Time Threat Assessment Resources Visit these websites for regularly updated information about current vector-borne disease threats and regional climate.
U.S. Dept. of State Travel Alerts
Health.mil Reports
CDC Current Outbreaks List
WHO Outbreak News
HealthMap Outbreaks
VectorMap Current Climate
AccuWeather Current Radar

Additional Resources
WHO Country Profile: Niger
CDC Travelers Guide: Niger
WRBU Medically Important Arthropod Species of the World

Militarily Important Vector-Borne Diseases with Short Incubation Periods (<15 days)	Vector
Malaria	Mosquito
Dengue Fever/ Yellow Fever/Chikungunya	Mosquito
West Nile Fever	Mosquito
Rift Valley Fever	Mosquito
Sindbis Virus	Mosquito
O'nyong-nyong Virus	Mosquito
Trypanosomiasis	Tsetse Fly
African Tick Bite Fever	Tick
Relapsing Fever (Tick-borne)	Tick
Crimean-Congo Hemorrhagic Fever	Tick
Boutonneuse Fever	Tick
Q-Fever	Tick
Militarily Important Vector-borne Diseases with Long Incubation Periods (>15 days)	**Vector**
Leishmaniasis	Sand Fly
Onchocerciasis	Black Fly
Bancroftian filariasis	Mosquito

Vector Hazard Report Quick Guide: Niger

Vector Identification Resources

Vector	Source
Mosquito	WRBU Pictorial Key to the Medically Important Mosquitoes of AFRICOM Edwards, F.W. (1941). Mosquitoes of the Ethiopian Region III—Culicine Adults and Pupae. Order of Trustees, British Museum of Natural History
Mosquito, *Anopheles*	Gillies, M. T., & Coetzee, M. (1987). A supplement to the Anophelinae of Africa South of the Sahara. Publ S Afr Inst Med Res, 55, 1-143.
Mosquito, *Aedes*	Rueda, L.M. 2004. Pictorial Keys for the Identification of Mosquitoes (Diptera: Culicidae) Associated With Dengue Virus Transmission. Zootaxa, 589: 1-60
Mosquito, *Culex*	Harbach, R.E. 1985. Pictorial keys to the genera of mosquitoes, subgenera of Culex and the species of *Culex* (*Culex*) occurring in southwest Asia and Egypt, with a note on the subgeneric placement of *Culex deserticola* (Diptera: Culicidae). Mosquito Systematics, 17: 83-107
Sand Fly	WRBU Pictorial Key to the Medically Important Sand Flies of AFRICOM
Tick, Ixodidae	Walker, A.R., Bouattour, A., Camicas, J.-L., Estrada-Pena, A., Horak, I.G., Latif, A.A., Pegram, R.G. & Preston, P.M. (2014) Ticks of Domestic Animals in Africa: a guide to identification of species. Bioscience Reports, Edinburgh, Scotland, UK.
Black Fly	Dang, P.T. & Peterson, B.V. 1980. Pictorial keys to the main species and species groups within the Simulium damnosum Theobald complex occurring in West Africa (Diptera: Simuliidae). Tropenmedizin und Parasitologie, 31(1): 117-120
Lice	University of Florida, Entomology and Nematology, Featured Creatures: Body Louse
Flea	CDC Pictorial Keys to Arthropods, Reptiles, Birds, and Mammals of Public Health Significance: Fleas

Insecticide Resistance Resources

Aedes sp. Insecticide Resistance (IR Mapper)
Anopheles sp. Insecticide Resistance (IR Mapper)
Test procedures for insecticide resistance monitoring in malaria vector mosquitoes (WHO)
Bottle Assay for Insecticide Resistance (CDC)

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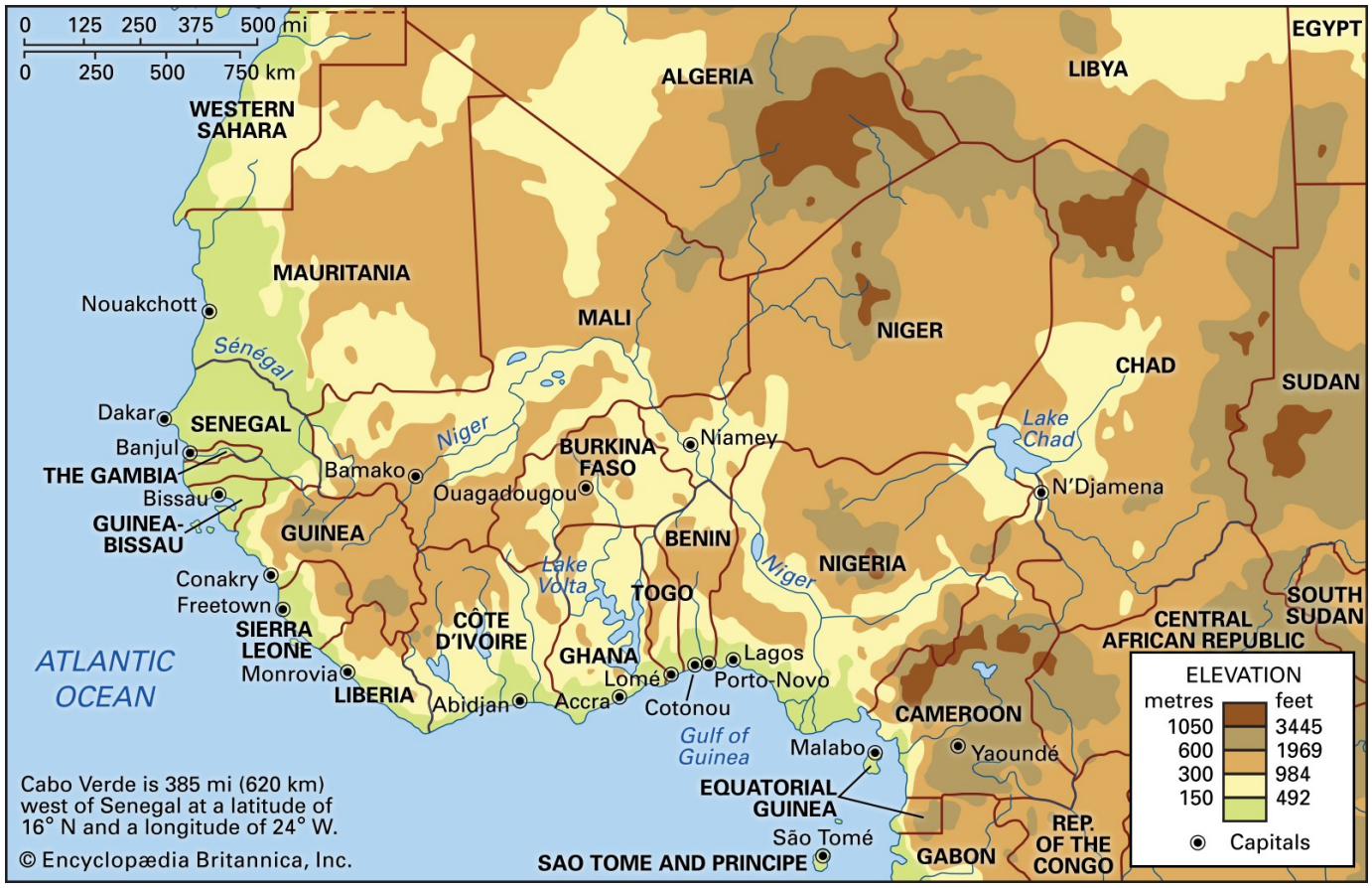
Topographic Map of Niger



Britannica, 2019

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Country Profile: Niger

Geography: Niger has a total land area of 1.267 million square miles making it slightly smaller than double the size of Texas, however, its water area is only 300 square miles. The country is naturally divided into three separate sections: (1) The northern desert (the Sahara) contains infertile soil outside of its sparse oases as well as highlands with valleys created by the mountain range, Air Massif, which contains mountains that exceed 1800 m. There are a number of "islands" in this region formed by groups of mountains. The northeast contains three plateaus forging a bridge between mountain ranges of Chad and Algeria. (2) An intermediate zone, the Sahel, contains nomads raising cattle in the center of the country. This region is home to numerous sand dunes in the west and is surrounded by the Nigerien Sahara to the north. (3) A southern cultivated region in which the majority of the population is located. This region contains a number of plateaus totaling nearly 1500 km in length which divide this area into three further sub regions. The west is known as the Djerma Ganda region, and contains large, sandy valleys that dip down from the Air Massif and Iforas Massif of Mali. Rocky, sandstone dominated terrain makes up the center of this region. Eastern areas of the south contain rocky, sandy land with some clay as well. Standing water is typically seen only in the southern region where the Niger River constitutes the border between Niger and Benin and in the basin of Lake Chad to the southeast.

CIA Factbook, 2019

Climate: The northern 4/5 of this country are dominated by the Sahara desert which blows harsh winds into the southern region hindering living conditions for many in January and February. Climate in the southern area is Sahelian and is defined by a singular, short rainy season per year lasting from one to four months dependent on latitude. The month of August is known as the rainy month in all parts of Niger with the exception of the northernmost parts in which precipitation is unpredictable. Temperatures here increase in February through May, decrease through the rainy season, rise once more, and then decrease into the lowest monthly averages during December or January. Nigerien temperatures are as high as 45°C in areas of the northern desert and as low as 108 °C around Lake Chad during the country's hottest month of May. January sees average temperatures in the mid 30s °C, but are capable of dropping to freezing temperatures throughout the desert. The temperature range of Niger is far greater in the northern desert than in the south and sees greater extremes in the dry season.

Population and Culture: The total population is 19,866,231 (July, 2018) with the highest population density seen in the southern border regions, such as the capital of Niamey (1.214 million), where the climate is much more mild than the northern desert. Nearly 1/5 of the country lives in cities and towns (18.7%) while the majority of the population is rural (81.3%). There are numerous ethnic groups throughout Niger: Hausa (53.1%), Zarma/Songhai (21.2%), Tuareg (11%), Fulani (6.5%), Kanuri (5.9%), and Others (2.3%). Multiple languages are spoken throughout Niger such as French, Djerma, and Hausa. Niger is predominantly Muslim (99.3%) with Christians (0.3%), animists (0.2%) and atheists (0.1%) constituting the small remainder. This country also has the highest total fertility rate in the world with an average of nearly 7 children per woman in 2016, adding to the vast inequality in age structure where 68.04% of the population is under 24 years old (48.68% are under 14). The literacy rate is 19.1%, and the life expectancy at birth is 56.3 years.

Official Languages: French

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Country Profile: Niger, cont.

Water, Living and Sanitary Conditions: Niger has inadequate health care facilities plus an overall poor state of health with the main obstacles for improvement being the inadequate amount of trained health care workers as well as a financial deficit. Rates of Trypanosomiasis and meningitis have significantly decreased and vaccines for other diseases have been handed out, however, diseases like malaria, leprosy, and tuberculosis are still endemic to Niger. The degree of risk for the major infectious diseases is very high according to the CIA as of 2016. The major vector-borne diseases are malaria and dengue fever, but other diseases such as schistosomiasis, rabies, and typhoid fever are also present. The percentage of the populations with access to water is only 58.2% (2015 est.) and is lower in the rural areas (48.6% rural, 100% urban), however, the CIA still advises U.S. citizens to drink bottled water when possible. Only 10.9% of the population has access to improved sanitation facilities including sewage systems, 16.2 % of the total population has access to electricity, and 4.3% has access to internet according to estimates in 2015. Niger is one of the poorest nations in the world with a per capita income of $420 and a poverty rate of over 44% according to the World Bank as of 2017. The UN designated it dead last in the Human Development Index in 2018.

Civil Unrest/ Conflict: The U.S. State Department has labelled the entirety of Niger with a travel advisory of Level 3: Reconsider Travel as of April, 2019, due to crime, terrorism, and kidnapping. The Department of State tells U.S. citizens to entirely avoid the Malian border region, Diffa region, and the Lake Chad region while requiring special authorization to be obtained if government workers desire to travel anywhere outside of the capital city of Niamey. There are numerous terrorist organizations, domestic and foreign, found throughout Niger with foci along the border regions with Mali, Libya, Burkina Faso and throughout northern Niger in the desert regions. Some of these groups include Islamic State of Iraq and ash-sham networks in the greater Sahara (ISGS), ISIS-West Africa, Boko Haram, and Jama'at Nusrat al'Islam wal-Muslimin (JNIM) which is an al-Qa'ida affiliate. All of these organizations seek either to replace regional governments with an Islamic state or to establish Islamic states and caliphates throughout West Africa as well as the continent as a whole. There have been numerous terrorist attacks within the last year such as the killings of 18 Nigerien soldiers in Tillaberi (July, 2019), killing of 2 police officers at the northern Niamey Gates (June, 2019), killings of 28 Nigerien soldiers in Tillaberi (May, 2019), and the killing of 12 people by suicide bombers and gunmen in Diffa (March, 2019). Kidnappings for ransom in the Sahel region by terrorists are common as well. Niger is also home to over 175,000 refugees due to violence and terrorism throughout West Africa with the predominant countries of origin being Nigeria and Mali (September, 2019 est.). The largest concentration of refugees is in the Diffa region.

[CIA World Factbook: Niger]

[Britannica: Niger]

[OSAC Crime & Safety Report 2019]

[State Department Niger Travel Advisory]

[UNHCR: Niger]

[CDC Travelers to Niger Health Information]

[CDC Travelers to Niger Healthy Packing List]

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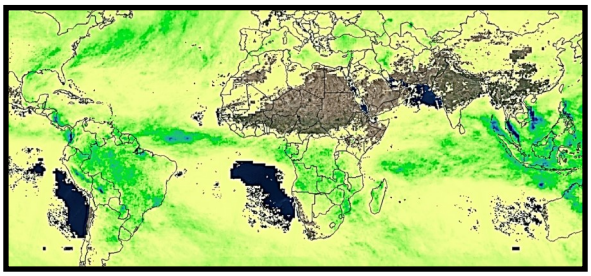
Monthly Climate Maps

Click here to view the maps described below



Rainfall

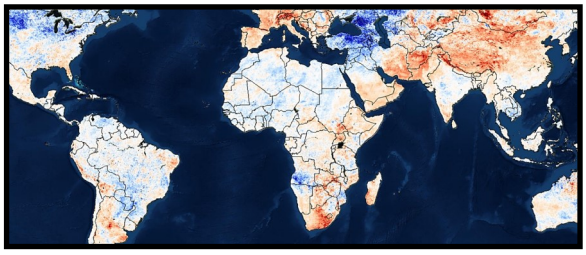
This map displays accumulated rainfall for the past month.

Consistent Above and Below Average Rainfall

This map displays areas with consistently above or below average monthly rainfall based on the previous three months. Above average rainfall may mean increased mosquito breeding habitat in areas with poor drainage. Below average rainfall can lead to increased domestic water storage providing increased mosquito breeding habitat.

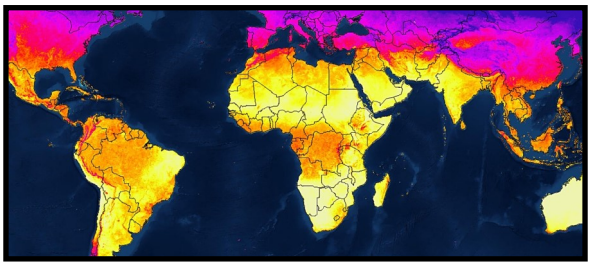
Drought-Breaking Rain

This map displays areas receiving above average rainfall for the previous month with below average rainfall for the previous 12 months. Drought-breaking rain may indicate suitable conditions for vectors and diseases in a stressed environment or population.



Temperature Anomaly

This map displays areas where the earth's temperature was warmer or cooler at the surface during the daytime over the expected average monthly temperatures (averaged over 2001-2010).



Land Surface Temperature

This map displays the temperature of the earths surface during the day-time.

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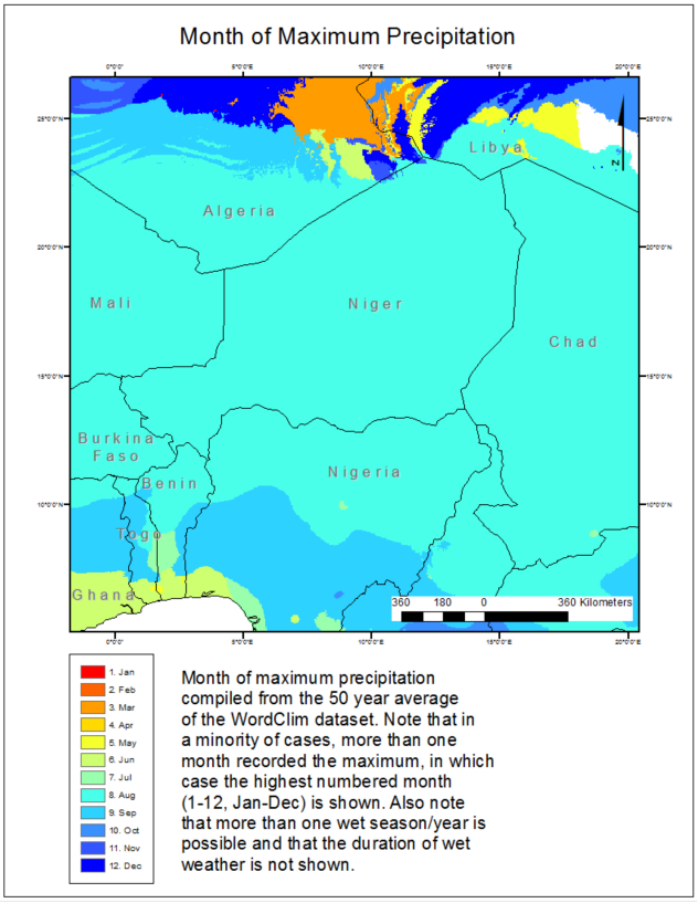
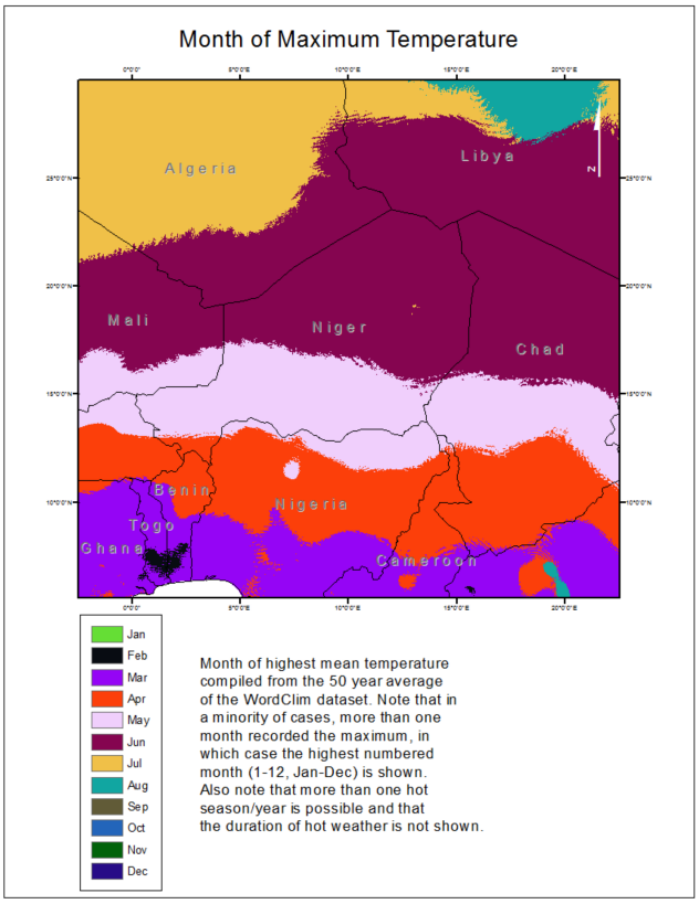
Climate of Niger





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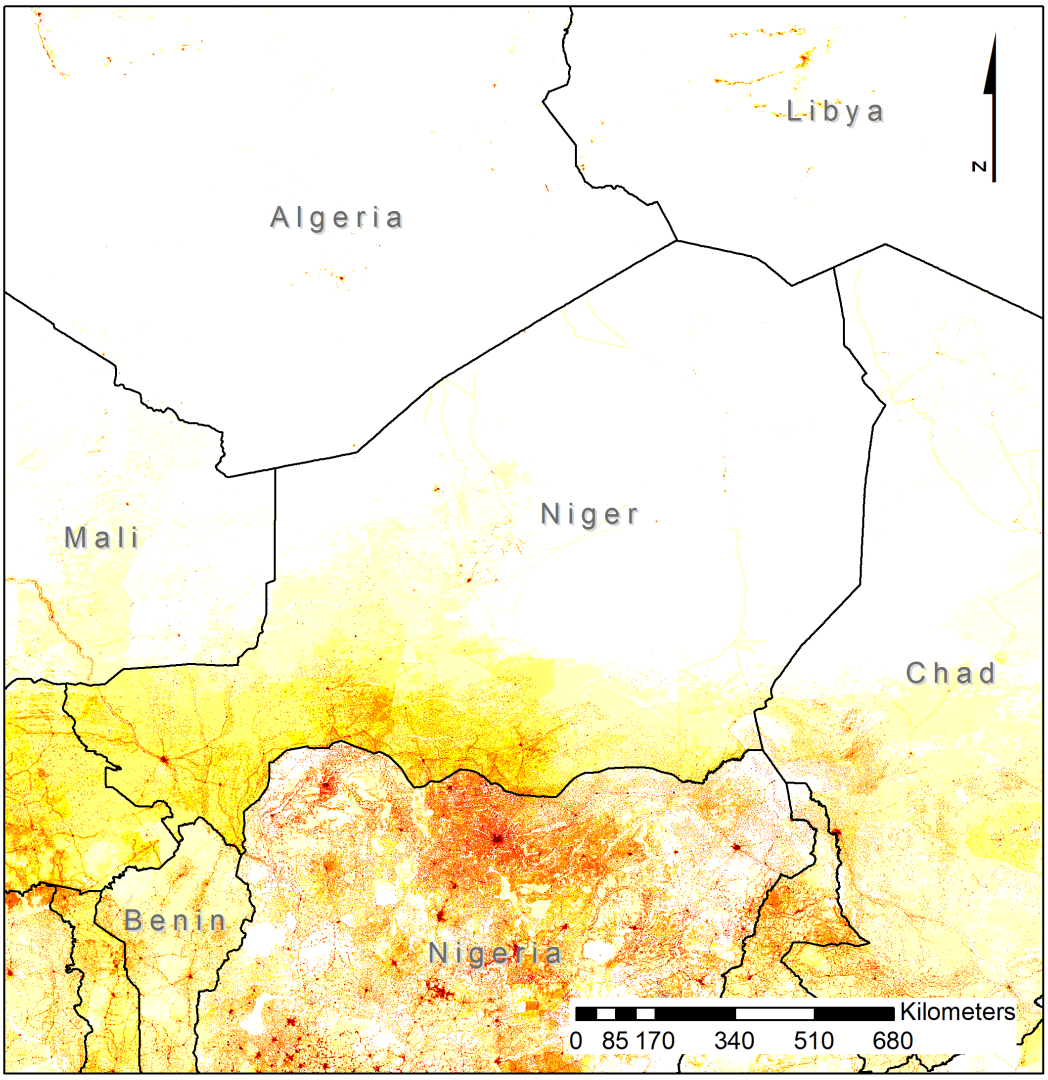
Human Density: Niger

Human Population



Population per sq km

- 0
- 1 - 5
- 6 - 25
- 26 - 50
- 51 - 100
- 101 - 500
- 501 - 2,500
- 2,501 - 5,000
- 5,001 - 185,000

This product was made utilizing the LandScan 2018 High Resolution global Population Data Set copyrighted by UT-Battelle, LLC, operator of Oak Ridge National Laboratory under Contract No. DE-AC05-00OR22725 with the United States Department of Energy. URL: https://landscan.ornl.gov/

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Vector-borne Disease Hazards

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Malaria

I. Disease Background: Human malaria is caused by protozoan species in the genus *Plasmodium* that are transmitted by the bite of an infective female *Anopheles* mosquito. Clinical symptoms of malaria vary with the species. The most serious malaria infection, *Plasmodium falciparum* malaria, can produce life-threatening complications, including renal and hepatic failure, cerebral damage, and coma. Case fatality rates among children and nonimmune adults exceed 10% when not treated. The other human malarias, *vivax*, *malariae* and *ovale*, are not life-threatening except in the very young, the very old, or persons in poor health. Illness is characterized by malaise, fever, shaking chills, headache, and nausea. The periodicity of the fever, occurring daily, every other day, or every third day, is characteristic of the species. Nonfatal cases of malaria are extremely debilitating. Relapses of improperly treated malaria can occur years after the initial infection in all but *falciparum* malaria. *Plasmodium malariae* infections may persist for as long as 50 years, with recurrent febrile episodes. Persons who are partially immune or have been taking prophylactic drugs may show an atypical clinical picture. In Niger, malaria is endemic and is a major public health issue as 100% of the population is at risk. Peak transmission directly follows the rainy season (May through October). Malaria also accounts for both 28% of all reported illnesses and 50% of all recorded deaths in the country (PMI, 2019). The potential attack rate could be as high as 50% per month in those exposed to mosquito bites in southern Niger. The more northern regions of Niger experience a shorter peak season, and decreased potential attack rate (1-10%) with most cases coming very near to rivers, streams and other permanent bodies of water (NCMI, 2019). Approximately 85% (or more) of the malaria cases are caused by *Plasmodium falciparum* while the remainder is caused by *P. ovale* (5-10%), and other malaria spp. are present but rare (CDC, 2019). *Plasmodium falciparum* is multidrug resistant throughout much of the country with chloroquine resistance present at an operationally significant level in and mefloquine resistance at lower levels (NCMI, 2019).

II. Military Impact and Historical Perspective: Historically, malaria has had an epic impact on civilizations and military operations. During World War I, in the Macedonian campaign, the French army was crippled with 96,000 cases of malaria. Malaria caused five times as many US casualties in the South Pacific as did enemy action. In 1942, during World War II, malaria was the major cause of casualties in General Stilwell's forces in North Burma. The Middle East was a notably malarious area during World War II. An annual incidence rate of 65 cases per 1,000 men for the four-year period was recorded. This rate was exceeded only by the incidence of malaria in the China-Burma-India Theater. US forces suffered a total of 273,566 cases of malaria throughout World War II, at a cost of 30,500 combat man-years. In 1952, during the Korean War, the 1st Marine Division suffered up to 40 cases per 1,000 marines. During the Vietnam War, many regiments were rendered ineffective due to the incidence of malaria and many US military units experienced up to 100 cases of malaria per 1,000 personnel per year. Elements of the 73rd Airborne Brigade had an incidence of 400 cases of malaria per 1,000 during 1967 to early 1968. Almost 300 military personnel contracted malaria during Operation Restore Hope in Somalia. Malaria remains a threat to military forces due to widespread drug resistance and disease resurgence in many areas of the world. Command enforcement of chemoprophylactic measures cannot be overemphasized. When Sir William Slim, British Field Marshal in Southeast Asia during World War II, strictly enforced chemoprophylactic compliance by relieving inattentive officers, attack rates of malaria declined dramatically. During the Vietnam War, malaria attack rates dropped rapidly in military personnel when urine tests were introduced to determine if chloroquine and primaquine were being taken. Many prophylactic drugs, such as chloroquine, kill only the erythrocytic stages of malaria and are ineffective against the latent hepatic stage of Plasmodium that is responsible for relapses. Therefore, even soldiers who take chloroquine appropriately during deployment can become infected. Individuals who are noncompliant with the prescribed period of terminal prophylaxis are at risk for late relapses upon their return to the US. During the Vietnam War, 70% of returning troops failed to complete their recommended terminal prophylaxis. The majority of cases in military personnel returning from Operation Restore Hope in Somalia resulted from failure to take proper terminal prophylaxis. In 2017, the WHO estimated that Niger accounted for 4% of the total ~435,000 malaria caused deaths (WHO, 2018). Malaria poses a high risk to U.S. military personnel in Niger and varies significantly with rainfall in the country (NCMI, 2019).

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Malaria

III. Transmission Cycle(s): Humans are the only reservoir of human malaria. Nonhuman primates are naturally infected by many *Plasmodium* species that can infect humans, but natural transmission is rare. Female mosquitoes of the genus *Anopheles* are the exclusive vectors of human malaria. *Plasmodium* species undergo a complicated development in the mosquito. When a female *Anopheles* ingests blood containing the sexual stages 68 (gametocytes) of the parasite, male and female gametes unite to form a motile ookinete that penetrates the mosquito's stomach wall and encysts on the outer surface of the midgut. Thousands of sporozoites are eventually released, and some of these migrate to the salivary glands. Infective sporozoites are subsequently injected into a human host when the mosquito takes a blood meal. The time between ingestion of gametocytes and liberation of sporozoites, ranging from 8 to 35 days, is dependent on the temperature and the species of *Plasmodium*. Malaria parasites develop in the mosquito vector most efficiently when ambient air temperatures are between 25 and 30° C. Parasite development is prolonged during cool seasons and at high altitudes, and may exceed the life expectancy of the vector. Once infected, mosquitoes remain infective for life. Vector competence is frequently higher with indigenous strains of malaria. This decreases the likelihood that imported strains from migrants will become established.

IV: Additional Resources:

CDC Malaria Travel Information

Malaria Atlas Project

President's Malaria Initiative: Niger

President's Malaria Initiative: Niger Operational Plan

Oldeburg, C.E., Guerin, P.J., Berthe, F., Grais, R.F. & Isanaka, S. (2018). Malaria and Nutritional Status among Children with Severe Acute Malnutrition in Niger: A Prospective Cohort Study. Clinical Infectious Diseases, 67(7): 1027-1034.

Sinka, M.E., Bangs, M.J., Manguin, S., Coetzee, M., Mbogo, C.M., Hemingway, J., Patil, A.P., Temperley, W.H., Gething, P.W., Kabaria, C.W., Okara, R.M., Boeckel, T.V., Godfray, H.C.J., Harbach, R.E., Hay, S.I. (2010). The dominant Anopheles vectors of human malaria in Africa, Europe and the Middle East: occurrence data distribution maps and bionomic precis. Parasites & Vectors, 3:117.

Chandramohan, D., Dicko, A., Zongo, I., et al. (2019). Effect of Adding Azithromycin to Seasonal Malaria Chemoprevention. The New England Journal of Medicine, 380: 2197-2206.

Grais, R.F., Laminou, I.M., Woi-Messe, L., et al. (2018). Molecular markers of resistance to amodiaquine plus sulfadoxine-pyrimethamine in an area with seasonal malaria chemoprevention in south central Niger. Malaria Journal, 98.

Gianotti, R.L., Bomblies, A., Dafalla, M., et al. (2008). Efficacy of local neem extracts for sustainable malaria vector control in an African village. Malaria Journal, 7:138.

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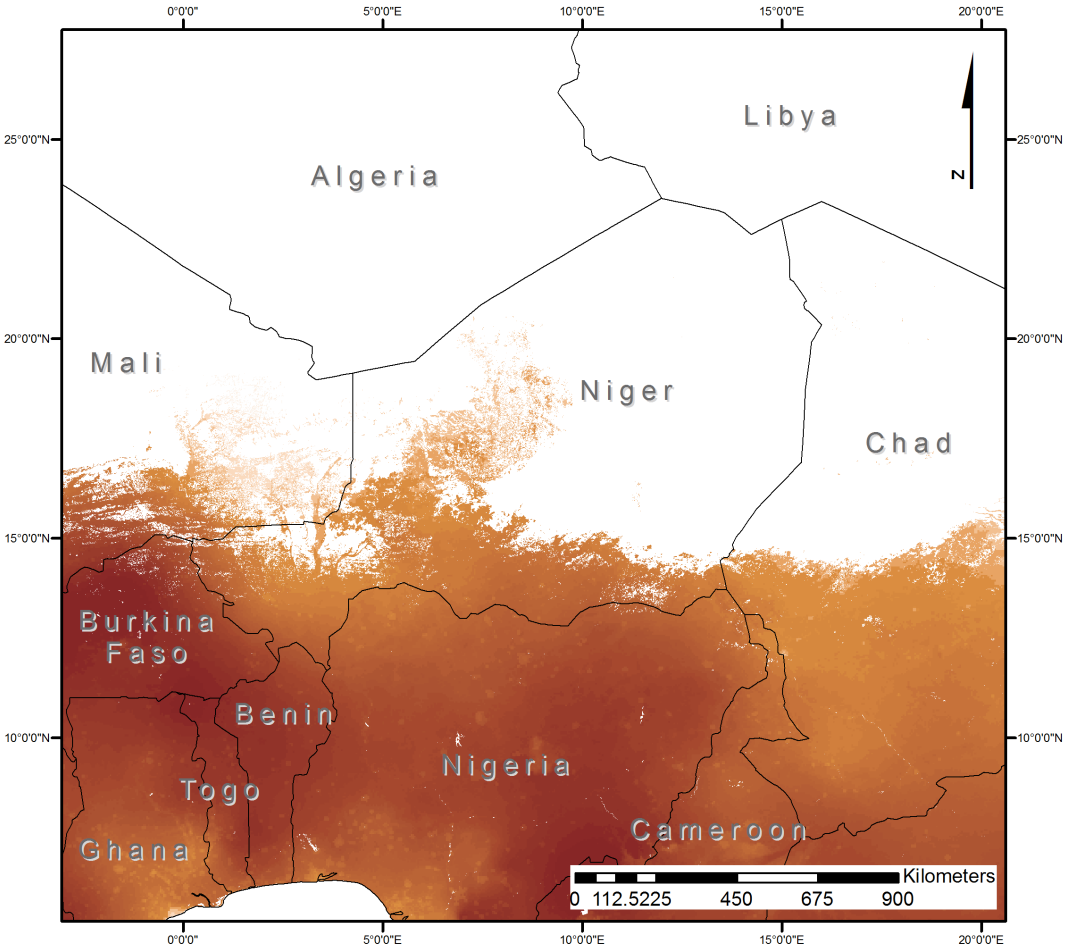
Malaria

Disease Distribution

Entomological Inoculation Rate

Plasmodium falciparum



Pf World (2010 - EIR)

Value

>100

0.1

The spatial distribution of Plasmodium falciparum entomological innoculation rate map in 2010 globally.This map shows point estimates of entomological inoculation rate (EIR) within the limits of stable Plasmodium falciparum transmission, illustrating the number of expected bites from infected mosquitoes per person per year. Malaria Atlas Project. Gething et al. (2011). Malaria Journal, 10: 378.

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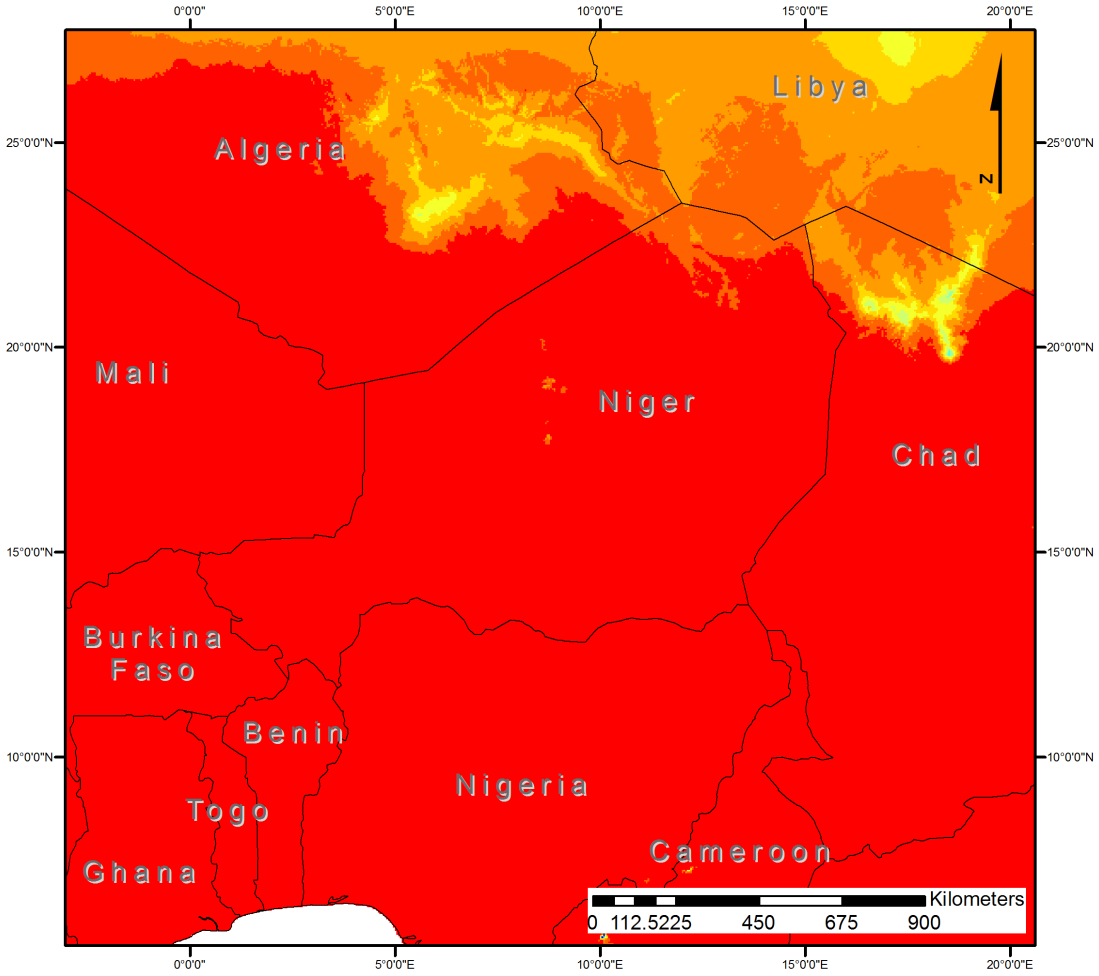
Malaria

Disease Distribution

Infectious Days

Plasmodium falciparum



- 1 month. Highly unsuitable for Pf
- 2 months
- 3 months
- 4 months
- 5 months
- 6 months
- 7 months
- 8 months
- 9 months
- 10 months
- 11 months
- 12 months. Highly suitable for Pf

The number of days in an average year (grouped into months) in which the annual temperature regime could support potentially infectious vectors
Source: Gething et al. Parasites & Vectors 2011, 4:92
http://www.parasitesandvectors.com/content/4/1/92

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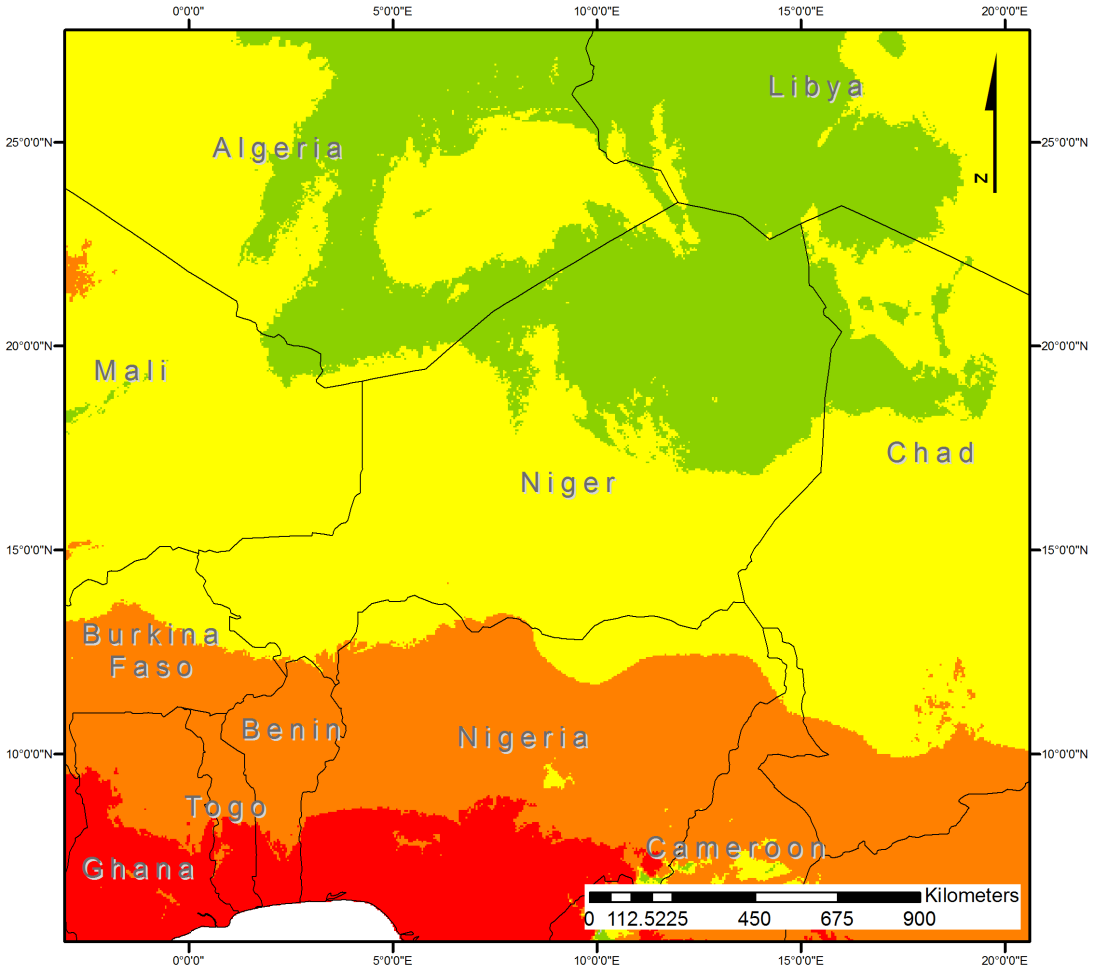
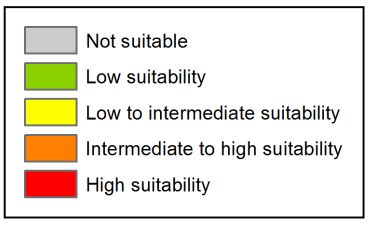
Malaria

Disease Distribution

Temperature Suitability Index

Plasmodium falciparum





The normalized Z(T) index of temperature suitability that incorporates not just the duration but also the degree of suitability across an average year
Source: Gething et al. Parasites & Vectors 2011, 4:92
http://www.parasitesandvectors.com/content/4/1/92

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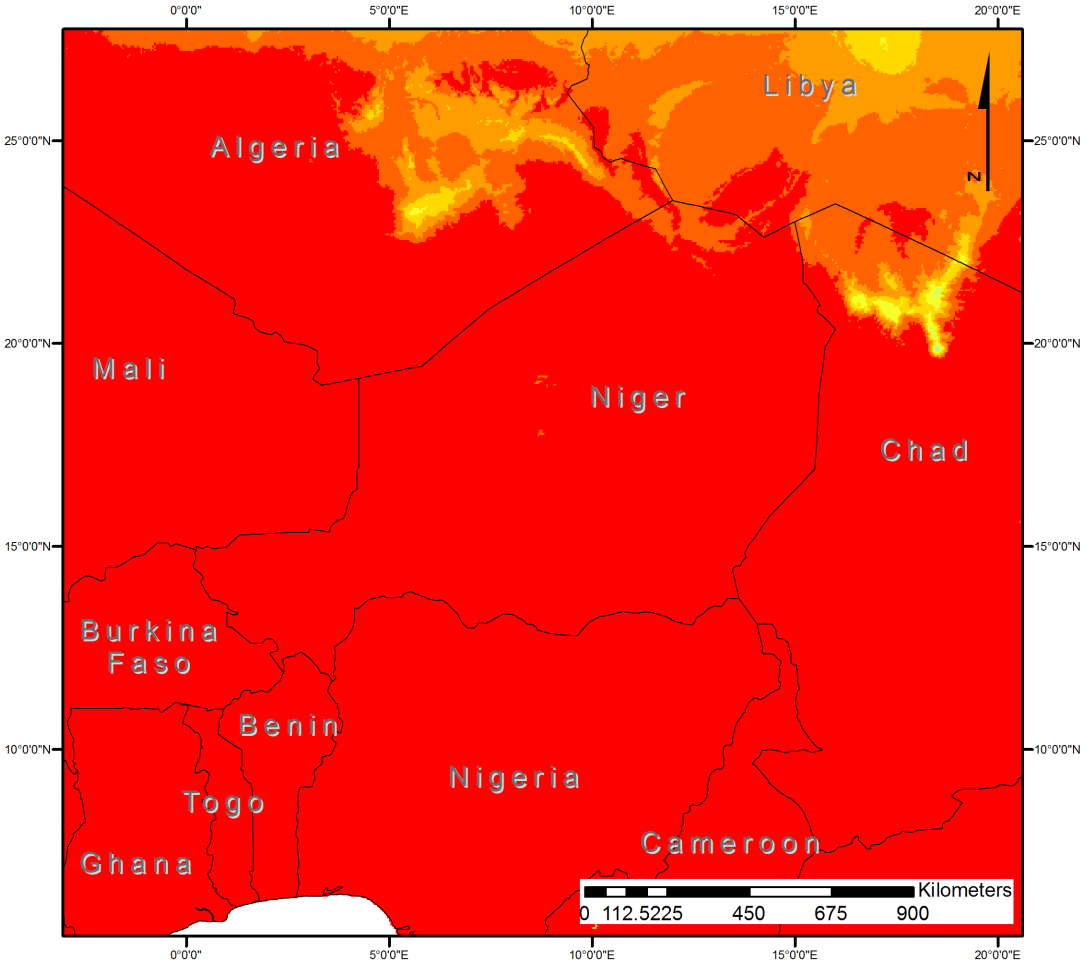
Malaria

Disease Distribution

Infectious Days

Plasmodium vivax



Pv World (Infectious days)

- 1 month. Highly unsuitable for Pv
- 2 months
- 3 months
- 4 months
- 5 months
- 6 months
- 7 months
- 8 months
- 9 months
- 10 months
- 11 months
- 12 months. Highly suitable for Pv

The number of days in an average year (grouped into months) in which the annual temperature regime could support potentially infectious vectors
Source: Gething et al. Parasites & Vectors 2011, 4:92
http://www.parasitesandvectors.com/content/4/1/92

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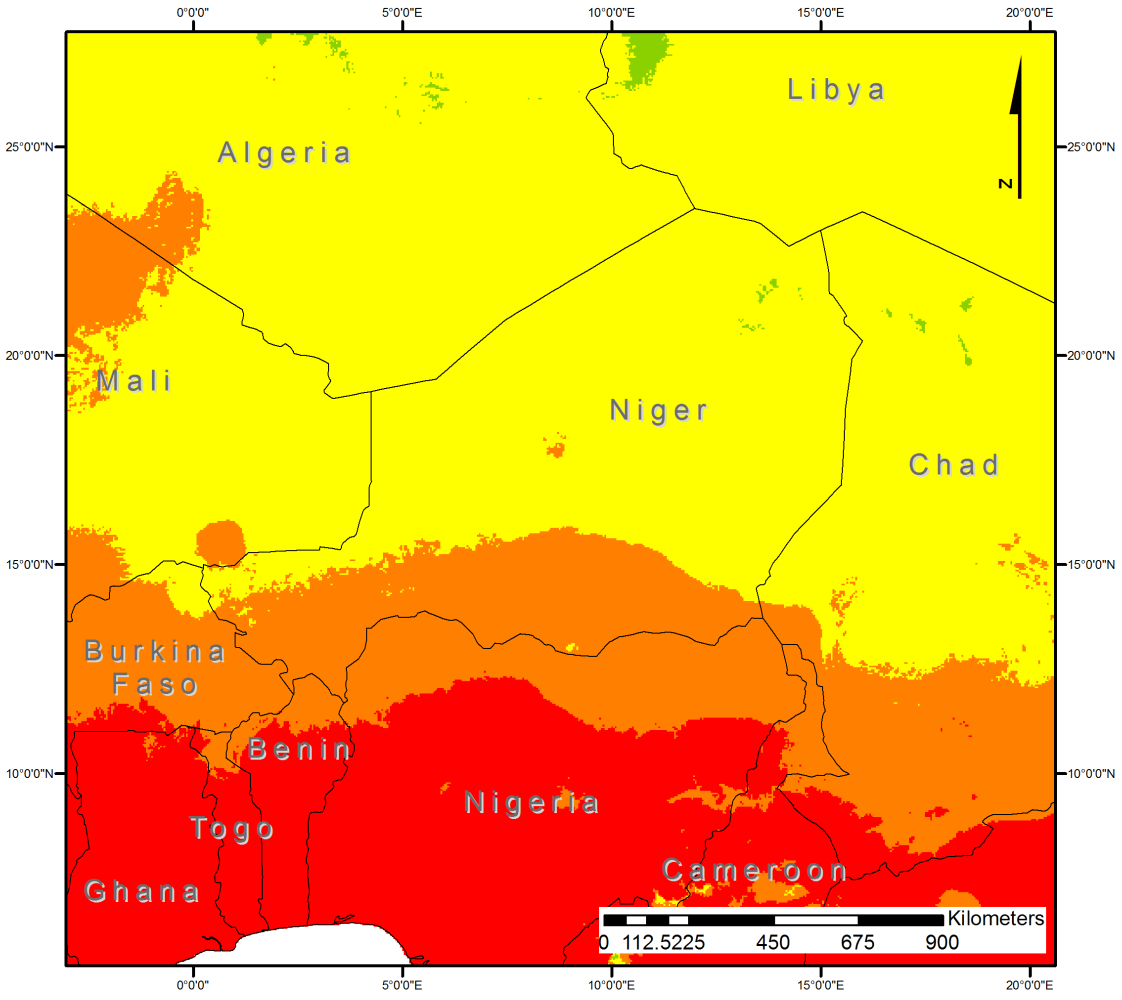
Disease Distribution

Temperature Suitability Index

Plasmodium vivax



- Not suitable
- Low suitability
- Low to intermediate suitability
- Intermediate to high suitability
- High suitability

The normalized Z(T) index of temperature suitability that incorporates not just the duration but also the degree of suitability across an average year
Source: Gething et al. Parasites & Vectors 2011, 4:92
http://www.parasitesandvectors.com/content/4/1/92

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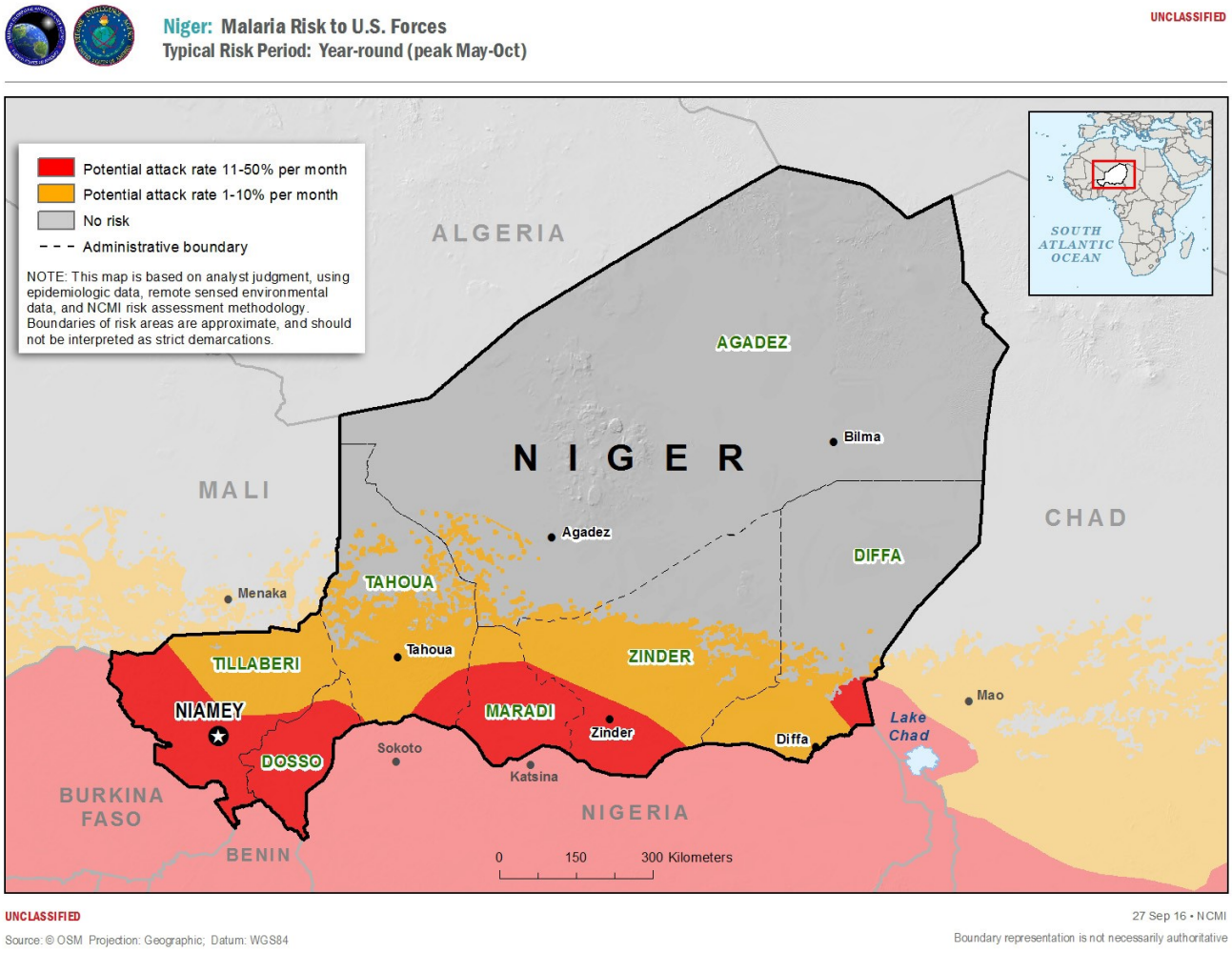
Malaria

Disease Distribution



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Dengue, Chikungunya & Yellow Fever Viruses

I. Disease Background:

Dengue fever (Breakbone fever, Dandy fever) is an acute febrile disease characterized by sudden onset, fever for 3 to 5 days, intense headache, and muscle and joint pain. It is commonly called breakbone fever because of the severity of pain. There is virtually no mortality in classical dengue. Recovery is complete, but weakness and depression may last several weeks. Dengue is caused by a *Flavivirus* and includes four distinct serotypes (dengue 1, 2, 3 and 4). Recovery from infection with one serotype provides lifelong immunity from the same serotype but does not protect against other serotypes. Dengue hemorrhagic fever (DHF) and associated dengue shock syndrome (DSS) were first recognized during a 1954 dengue epidemic in Bangkok, Thailand. DHF/DSS have spread throughout Southeast Asia, Indonesia and the southwest Pacific, Latin America and the Caribbean. DHF requires exposure to two serotypes, either sequentially or during a single epidemic involving more than one serotype. DHF is a severe disease that produces high mortality in children. Yellow fever (YFV) is an acute viral haemorrhagic disease belonging to the genus *Flavivirus* characterized by the "yellow" tone of some patients of severe YFV due to jaundice. This more toxic phase of YFV usually begins within one day of the end of the initial symptoms. Severe YFV affects ~15% of patients and its symptoms include high fever, shock, organ failure, bleeding, etc. Other more mild symptoms include fever, chills, severe headache, body aches, nausea, vomiting and fatigue. However, the majority of those infected with YFV have mild or no symptoms before completely recovering. The first infection a person may contract will often grant immunity to future YFV infections. Yellow fever is endemic to tropical areas of Central and South America and Africa where outbreaks are common. A vaccine is required for travelers arriving in Niger over the age of 1 and is recommended for travelers of the same age as they leave the country. There are 3 main types of YFV: Sylvatic (jungle), intermediate (savanna) and urban. Chikungunya refers to an infection by the Chikungunya virus (CHIKV). CHIKV is primarily transmitted by *Ae. aegypti* and *Ae. albopictus*. The name means "that which bends up" in the native language of southeastern Tanzania, and refers to the symptoms of Chikungunya fever. CHIKV symptoms typically include a sudden high fever and severe joint pain. Headache, back pain, muscle pain, nausea, vomiting, arthritis, rash, and conjunctivitis may also occur. Unlike Dengue, CHIKV is currently thought to be nonfatal.

II. Military Impact and Historical Perspective:

Dengue virus was first isolated and characterized in the 1940s, but dengue fever had been identified clinically from the 18th century. Epidemics of dengue are noted for affecting a large proportion of the population in a community or in military forces operating in an endemic area. Outbreaks involving 500,000 to 2 million cases have occurred in many parts of the world. During World War II, at Espiritu Santo in the Pacific, an estimated 25% of US military personnel became ill with dengue, causing a loss of 80,000 man-days. Other campaigns in the Pacific were marked by dengue epidemics, and throughout the war the US Army experienced nearly 110,000 cases. Dengue was an important cause of febrile illness among US troops during Operation Restore Hope in Somalia. In recent years dengue, especially DHF, has been expanding throughout the world. 30 to 50 million cases of dengue are reported annually. Transmission is unlikely in the northern desert of Niger, however, vectors are present in the south. CHIKV typically occurs as sudden, unpredictable and explosive outbreaks in susceptible populations including new groups of people who enter an endemic region and have not encountered the virus, lowering overall immunity in the region. Outbreaks of CHIKV historically have occurred in Africa and Asia. In 2007, the virus was found to be spreading in northern Italy and in December 2013 was found in the Caribbean. CHIKV has also been detected within populations of refugees fleeing Syria and traveling through Turkey. Yellow fever has been known to the western world since the mid-17th century with dozens of outbreaks having occurred since. U.S. Army physicians, including Walter Reed, first discovered that mosquitoes vectored and transmitted YFV in the year 1900. Under reporting of the disease is very common with WHO estimating that less than 1% of cases are reported worldwide which makes it difficult to assess the actual number of cases per year. Yellow Fever transmission is unlikely in the Sahara Desert, however, sporadic cases can occur in the south.. The risk of dengue to military personnel in Niger is high overall, but highest in urban and other densely populated areas and lowest in sparsely populated areas. The risk of YFV in Niger is intermediate year round with an elevated risk during and immediately after the rainy seasons; May through October. Chikungunya poses an intermediate risk to U.S. military personnel, however, in areas of high density (similar to dengue) the possibility of unpredictable and explosive transmission increases could lead to outbreaks (NCMI, 2019).

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Dengue, Chikungunya & Yellow Fever Viruses

III. Transmission Cycle(s):

Dengue virus is exclusively associated with *Aedes* mosquitoes in the subgenus *Stegomyia.* The virus is maintained in a human-*Ae. aegypti* cycle in tropical urban areas. Mosquitoes are able to transmit dengue virus 8 to 10 days after an infective blood meal and can transmit the virus for life. Yellow Fever has three types with different transmission cycles: (1) Sylvatic (jungle) yellow fever where the disease is passed from monkey to human from infected mosquitoes. (2) Intermediate (savanna) yellow fever is the most common outbreak inducing type and is caused by semi-domestic mosquitoes in close proximity to both humans and non-human primates. (3) Urban yellow fever is transmitted by *Aedes aegypti* between humans only (no other primates). Chikungunya virus is also spread via *Aedes* mosquitoes, primarily *Aedes aegypti*.

IV. Additional Resources:

CDC Dengue Fever Background

CDC Chikungunya Background

CDC Yellow Fever Background

WHO Dengue Outbreak Information

WHO Chikungunya Outbreak Information

WHO Yellow Fever Outbreak Information

AFPMB Technical Guide No. 47. Aedes Mosquito Vector Control. Office of the Assistant Secretary of Defense (Energy, Installations and Environment). 2016.

Fagbami, A.H. & Onoja, A.B. (2018). Dengue haemorrhagic fever: An emerging disease in Nigeria, West Africa. Journal of Infection and Public Health, 11(6): 757-762.

Jean, K., Hamlet, A., Dorigatti, I., et al. (2018). Responding to yellow fever outbreaks in West and Central Africa: Rapid prioritization assessment for the preemptive vaccination campaigns. Revue d'Epidemiologie et de Sante Publique, 66(5), S392.

Ajogbasile, F.V., Oguzie, J.U., Oluniyi, P.E., et al. (2019). Real-time Metagenomic Analysis of Undiagnosed Fever Cases Unveils a Yellow Fever Outbreak in Edo State, Nigera. bioRxiv 572354, doi: https://doi.org/10.1101/572354

Zeller, H., Bortel, W.V., & Sudre, B. (2016). Chikungunya: Its History in Afria and Asia and Its Spread to New Regions in 2013-2014. The Journal of Infectious Diseases, 214(2): S436-40.

Petersen, L.R. & Powers, A.M. (2016). Chikungunya: epidemiology. F1000Research, 5(F1000Faculty Rev): 82.

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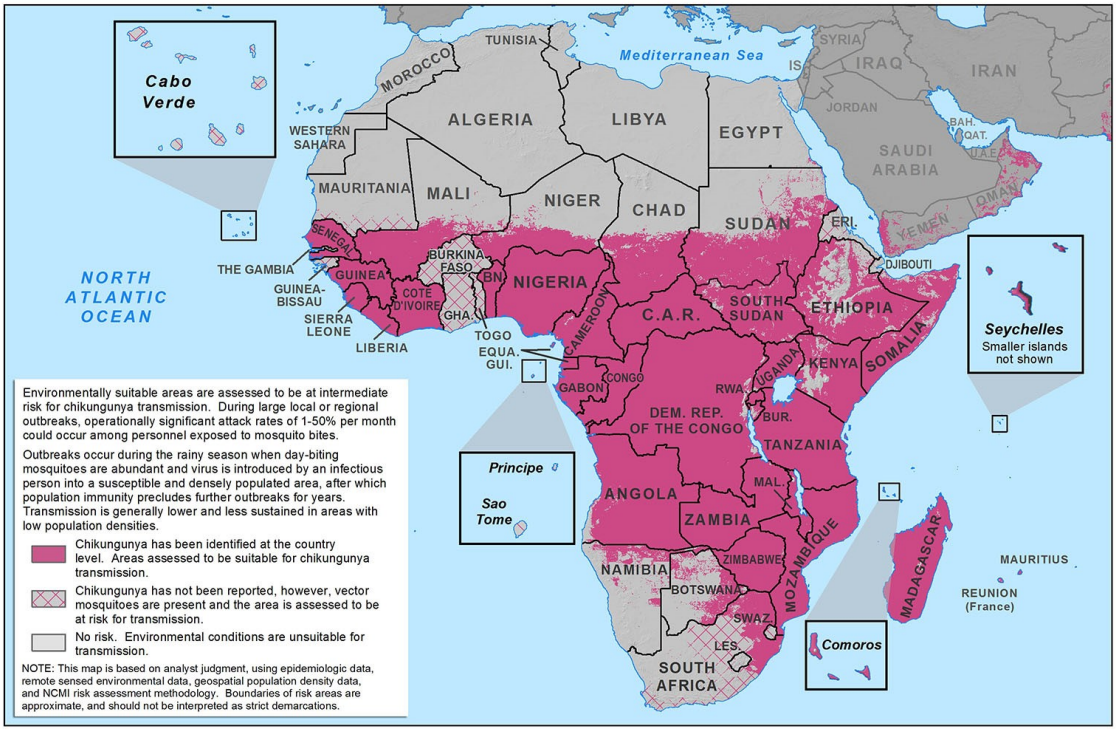
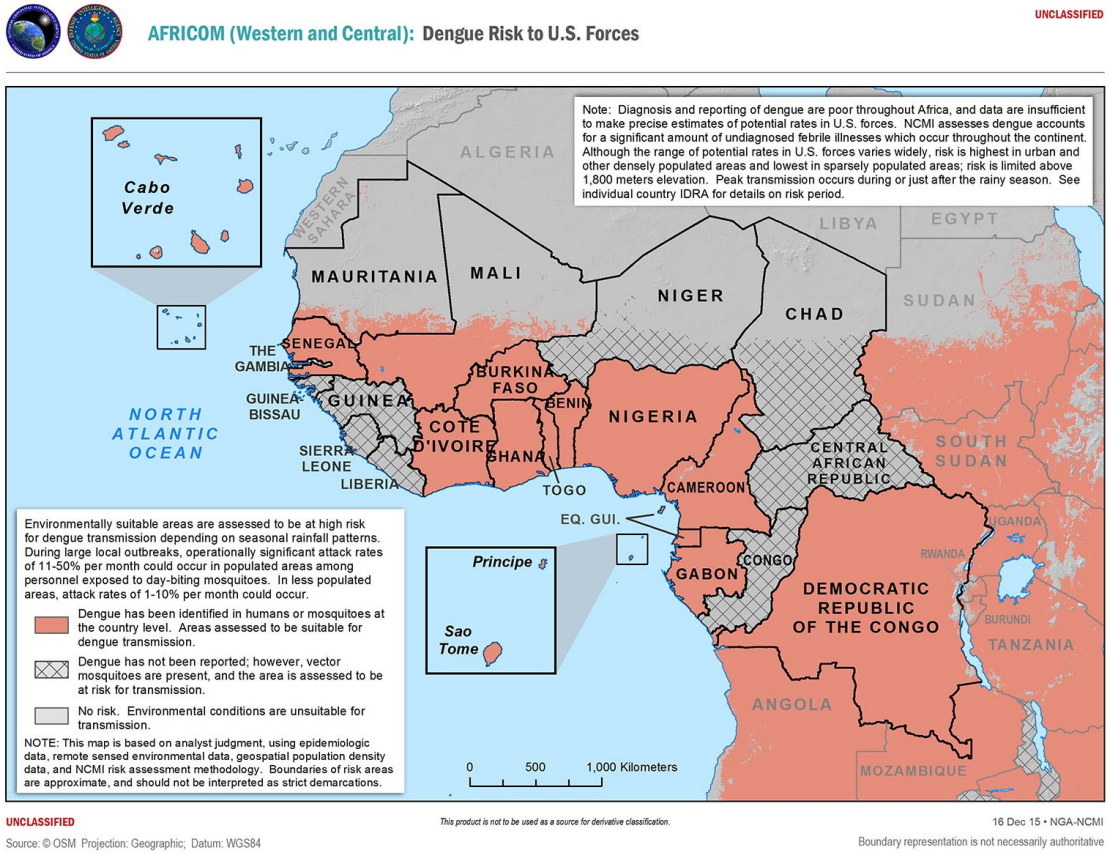
Dengue, Chikungunya & Yellow Fever Viruses





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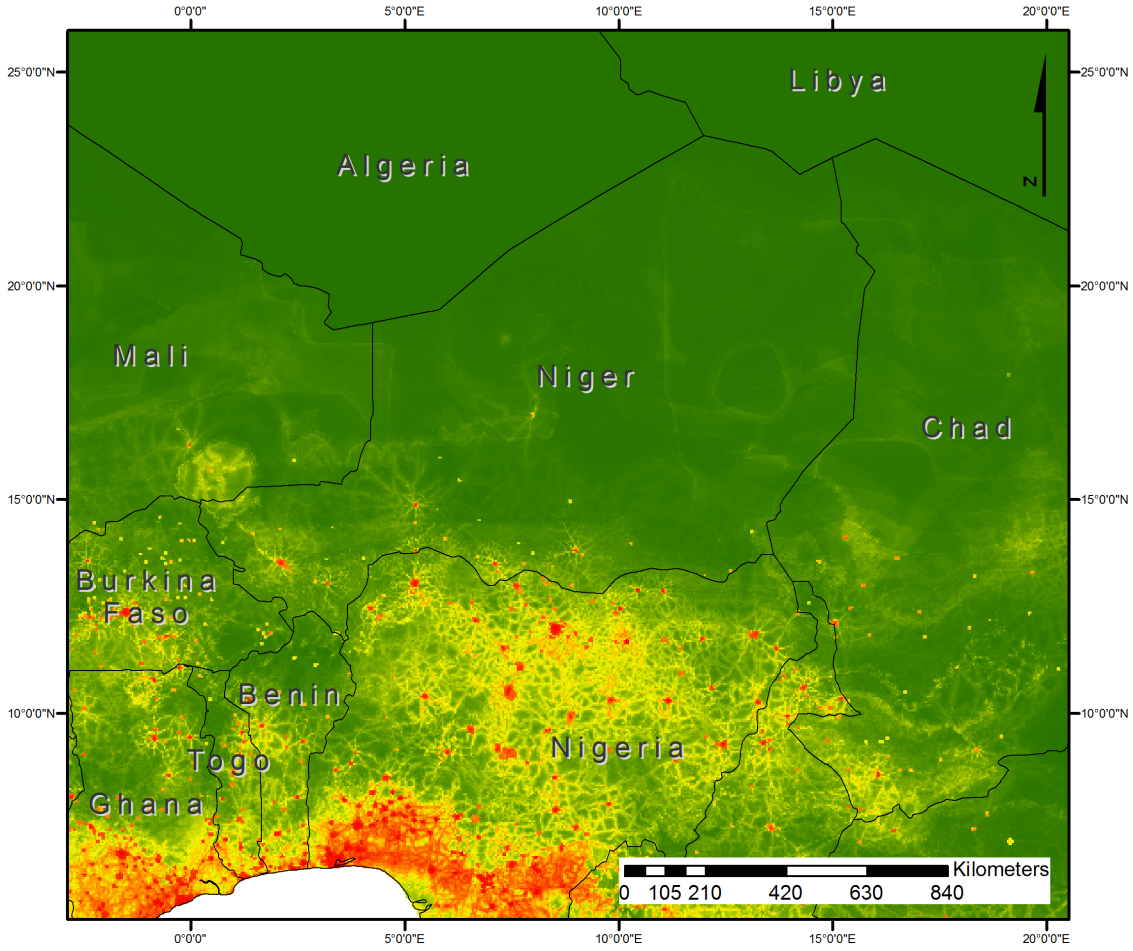
Dengue, Chikungunya & Yellow Fever Viruses

Dengue Fever Risk Model



Dengue risk model

Prob. of occurrence : 1

Prob. of occurrence : 0

The probability of dengue occurrence (risk) map is the central tendency of an ensemble of 336 boosted regression tree (BRT) models that used different plausible combinations of the main biasing factors. For a more complete description of the methods see:
Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, et al. (2013) The global distribution and burden of dengue. Nature 496: 504-507

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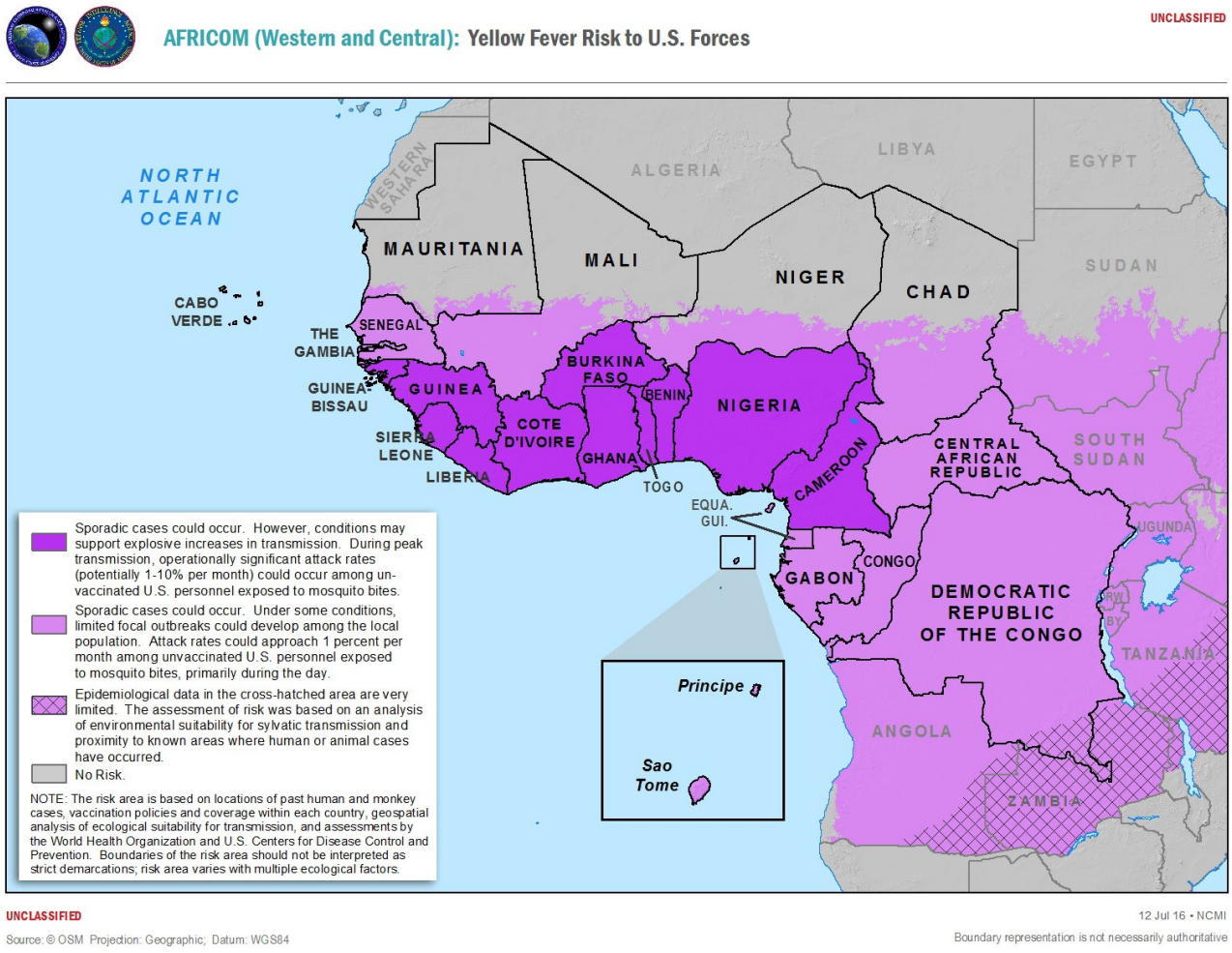
Dengue, Chikungunya & Yellow Fever Viruses



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West Nile Virus

I. Disease Background: West Nile fever is a mosquito-borne illness characterized by fever, headache, muscular pain, and rash. Occasionally, serious complications involve the liver and nervous system. The etiological agent, West Nile virus (WNV), is named after the district of Uganda where the virus was first isolated. It is a Flavivirus closely related to viruses causing Japanese encephalitis and St. Louis encephalitis. Infection with WNV is most often asymptomatic. The incubation period ranges from 1 to 6 days and clinically resembles a mild dengue-like illness.

II. Military Impact and Historical Perspective: WNV was first isolated in 1937 and was one of the earliest human arboviral infections to be documented. Undoubtedly, WNV has been the cause of many cases classified as fevers of unknown origin in military personnel. Infection with WNV will complicate diagnoses by medical personnel, since West Nile fever cannot be clinically distinguished from many other arboviral fevers. Epidemics of West Nile fever are infrequent, and continued long-term surveillance for virus activity can rarely be justified when considering other health care demands. Reduction of mosquito populations by ULV spraying may be useful as a means of disease control. The most feasible long-term control strategies involve reducing vector breeding by environmental management techniques. Personal protective measures to prevent mosquito bites are the most practical means of avoiding infection with WNV. The threat of WNV to military personnel is intermediate countrywide, year round with peak transmission immediately following the rainy season from May through October despite the lack of recently reported cases from the country (NCMI, 2019).

III. Transmission Cycle(s): WNV has been isolated from numerous wild birds and mammals. Serological surveys have demonstrated WNV antibodies in wild and domestic bird species, wild mammals such as lemurs, rodents and bats, and domestic animals such as camels, horses, mules, donkeys, goats, cattle, water buffalo, sheep, pigs and dogs. However, birds are considered to be the primary reservoir for WNV and may reintroduce the virus during seasonal migrations. Infections in most mammals fail to produce viremias high enough to infect potential vectors. WNV has been isolated from several species of mosquitoes in nature, and they are recognized as the major vectors, especially *Culex* spp. WNV has also been recovered from bird-feeding ticks and mites. A natural bird-tick zoonotic cycle has been suggested, but the role of ticks in the natural transmission of WNV has not been well defined. Mosquitoes are clearly implicated in the transmission of WNV to humans. WNV replicates quickly in mosquitoes when temperatures exceed 25°C. Infected mosquitoes can transmit WNV for life.

IV. Additional Resources:

CDC West Nile Virus Background

WHO West Nile Virus Background

Sule, W.F., Oluwayelu, D.O., Hernandez-Triana, L.M., Fooks, A.R., Venter, M. and Johnson, N. (2018). Epidemiology and ecology of West Nile virus in sub-Saharan Africa. Parasites & Vectors, 11:414

Fall, G., Faye, M., Weidmann, M., et al. (2016). Real-Time RT-PCR Assays for Detection and Genotyping of West Nile Virus Lineages Circulating in Africa. Vector-Borne and Zoonotic Diseases, 16(12).

Fall, G., Paola, N.D., Faye, M., et al. (2017). Biological and phylogenetic characteristics of West Africa lineages of West Nile virus. PLoS Neglected Tropical Diseases, 11 (11): e0006078.

Lafri, I., Hachid, A., & Bitam, I. (2019). West Nile virus in Algeria: a comprehensive overview. New Microbe and New Infections, 27:9-13.

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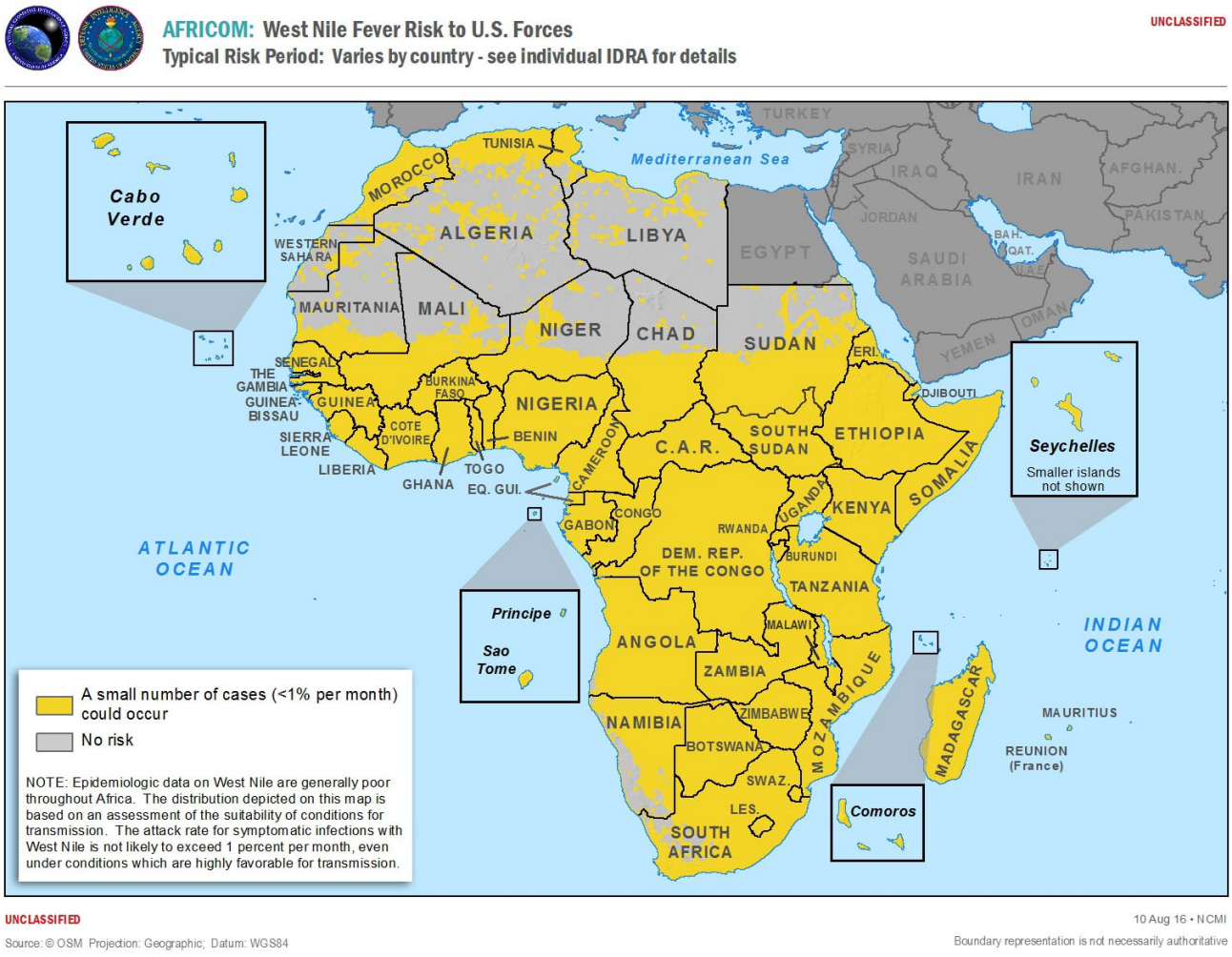
West Nile Virus



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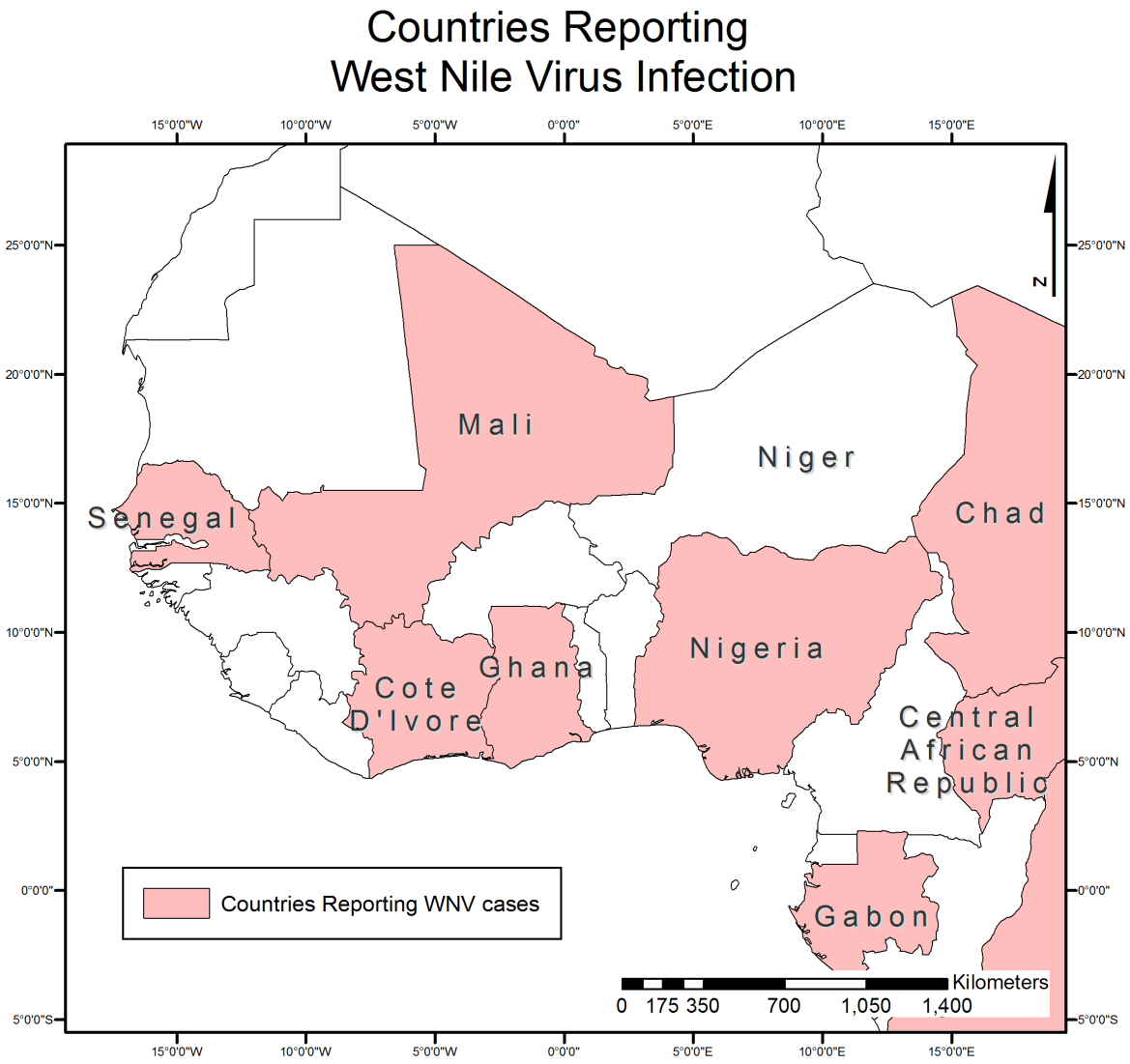
West Nile Virus



Countries of sub-Saharan Africa where WNV has been isolated or WNV has been detected by serosurveillance and those where no evidence for WNV has been found or no studies have been reported. From: Sule, W. F., Oluwayelu, D. O., Hernández-Triana L. M., Fooks, A. R., Venter, M., & Johnson, N. (2018). Epidemiology and ecology of West Nile virus in sub-Saharan Africa. Parasites & Vectors, 11(1), 414.

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Sindbis virus

I. Disease Background: Sindbis virus belongs to the genus *Alphavirus* in the family *Togaviridae*. It is closely related to the Western equine encephalitis complex. The incubation period is less than a week and symptoms may include fever, headache, rash, and joint pain. Syndromes resulting from Sindbis virus infection have been called Ockelbo disease in Sweden, Pogsta disease in Finland, and Karelian fever in the former Soviet Union. No fatal cases have been reported.

II. Military Impact and Historical Perspective: Sindbis virus was first isolated in 1952 from *Culex* mosquitoes collected in the village of Sindbis north of Cairo. A role in human disease was recognized in 1961 when Sindbis virus was isolated from patients with fever in Uganda. Sindbis poses a low threat to U.S. personnel primarily in rural areas with elevated risk directly following the rainy season from May through October (NCMI, 2019).

III. Transmission Cycle(s): A wide range of wild and domestic vertebrate species are susceptible to infection with Sindbis virus. Most experimentally infected wild bird species easily produce viremias high enough to infect several different species of mosquitoes. Wild and domestic birds are considered the main enzootic reservoir. Although several species of domestic animals can become infected with Sindbis virus, there is no evidence that these infections result in significant illness. Evidence implicates bird-feeding mosquitoes of the genus *Culex* as the vectors of Sindbis virus in enzootic and human infections. However, viral isolations and transmission experiments have shown that *Aedes* spp., which are less host specific and feed readily on both birds and humans, may be important as vectors linking the enzootic cycle with human infection. Mechanisms that allow the virus to overwinter and survive between periods of enzootic transmission have not been identified.

IV. Additional Resources:

ECDC Sindbis Virus Background

Ling, J., Smura, T., Lundstrom, J.O., et al. (2019). Introduction and Dispersal of Sindbis Virus form Central Africa to Europe. Journal of Virology, 93(16): e00620-19.

O'nyong-nyong virus

I. Disease Background: O'nyong-nyong virus (ONNV) belongs to the genus *Alphavirus* in the family *Togaviridae* and is closely related to Chikungunya virus. The incubation period it typically 3 to 11 days and leads to symptoms of headache, pruritic rash, lymphadenopathy, and conjunctivitis. While there is no targeted treatment, patients are incapacitated for 2 weeks at most and then recover completely– no fatal cases have been reported.

II. Military Impact and Historical Perspective: O'nyong-nyong was first isolated in 1959 from serum samples in the Northern Province of Uganda. The virus has since caused two wide spread epidemics in East Africa from 1959 to 1962 affecting 2 million people and again in 1996 at a smaller scale. In the fall of 2003, an outbreak of febrile illness in a group of 8000 Libyan refugees residing in Cote d'Ivoire contained 8 individuals who tested positive for ONNV (Posey *et al.*, 2005). O'nyong-nyong is primarily a disease of East Africa, however, presumed strains of ONNV are present in West Africa and its vectors are present (Posey *et al.,* 2005). While not fatal, symptoms of O'nyong-nyong can hospitalize military personnel.

III. Transmission Cycle(s): While a vertebrate host has yet to be identified, cattle and other domestic livestock as well as several species of rodents have been implicated in serological surveys. Uniquely, this virus is spread by mosquitoes of the genus *Anopheles* in Kenya making it the only known human alphavirus vectored by anophelines.

IV. Additional Resources:

Army Public Health Command Fact Sheet

CDC O'nyong-nyong Virus Background

Rezza, G., Chen R. and Weaver, S.C. (2017). O'nyong-nyong fever: a neglected mosquito-borne viral disease. Pathogens and Global Health, 111(6): 271-275.

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Rift Valley Fever Virus

I. Disease Background: A *Phlebovirus* of the family *Bunyaviridae* causes Rift Valley fever (RVF). Humans infected with RVF typically have either no symptoms or a mild illness associated with fever and liver abnormalities. However, in some patients the illness can progress to hemorrhagic fever with shock or hemorrhage, encephalitis with coma or seizures, and/or ocular disease. Patients who become ill usually experience fever, generalized weakness, back pain, dizziness and weight loss at onset of fever. Typically, patients recover within one week after onset of illness. The most common complication associated with RVF is inflammation of the retina resulting in permanent vision loss in 1 to 10% of affected patients. Approximately 1% of patients die of the disease, but case fatality rates are significantly higher for infected animals. Nearly 100% of pregnant livestock infected with RVF virus abort their fetuses. Human outbreaks usually take place following outbreaks in sheep, cattle, or camels. There is no established course of treatment for infected patients, although some antiviral drugs such as ribavirin show promise.

II. Military Impact and Historical Perspective: Veterinary officers in Kenya first reported RVF among livestock in the early 1900s, although the virus wasn't isolated until 1930. The most notable epizootic occurred in South Africa during 1950 to 1951 and was estimated to have caused the death of 100,000 sheep and cattle and to have involved 20,000 human cases. In 1977, the virus was detected in Egypt and caused a large outbreak among animals and humans. The first epidemic of RVF in West Africa was reported in 1987 and was linked to the Lower Senegal River Project. The project caused flooding in the lower Senegal River area that produced large populations of mosquitoes. A recent outbreak occurred in Niger in 2016, and lead to approximately 90 cases and 28 deaths in humans as well as substantial livestock and cattle death. The main demographic hit by this outbreak were nomadic stockbreeders and traders (Tambo, 2016). During epizootics, RVF could seriously affect military operations. Five percent of Swedish United Nations Emergency Forces soldiers serving in Egypt and the Sinai peninsula were infected with RVF virus during the 1977-78 epidemic in Egypt. Medical personnel should be aware of clinical and diagnostic procedures to differentiate RVF from other fevers with similar clinical syndromes. Risk of Rift Valley fever to military personnel is intermediate overall with risk being highest in rural areas, in areas with close proximity to livestock, and immediately following the rainy season from May through October (NCMI, 2019).

III. Transmission Cycle(s): RVF primarily affects domestic animals such as cattle, buffalo, sheep, goats and camels. High viremias occur in infected humans. Thus, humans, as well as domestic animals, could be a source of virus to infect potential vectors. Mosquitoes transmit RVF virus. Unlike most arboviruses that are associated with either a single species or closely related group of mosquitoes, RVF virus has been isolated from at least 28 species in six genera of mosquitoes. Epizootics have generally occurred during years of excessive rainfall and localized flooding that produced large populations of mosquitoes. RVF virus may be transmitted by other blood-sucking arthropods. *Culex pipiens* was implicated as the principal vector during the 1977-78 epidemic in Egypt. Vector competence studies and knowledge of mosquito density and feeding behavior in areas where RVF virus infections have occurred suggest that these species may be the principal vectors involved in domestic animal transmission and as bridge vectors from domestic animals to humans. In contrast, *Cx. pipiens* appears to be the principal vector for human-to-human transmission. Transovarial transmission of the virus is known to occur in some mosquito species. Humans can also acquire infection if they are exposed to the blood or other body fluids of infected animals. This exposure can result from the slaughtering or handling of infected animals or by touching contaminated meat during the preparation of food. Abattoir workers are a useful sentinel population for surveillance of RVF virus. Laboratory infection through aerosol transmission of RVF virus has resulted from exposure to specimens containing the virus.

IV. Additional Resources:

CDC Background: Rift Valley Fever Virus

Ndiaye, E.H., fall, G., Gaye, A., Bob, S.N., Talla, C., Diagne, C.T., Diallo, D., Yamar, B.A., Dia, I., Kohl, A., Sall, A.A. and Diallo, M. (2016). Vector competence of *Aedes vexans* (Meigen), *Culex poicilipes* (Theobald) and *Cx. quinquefasciatus* Say from Senegal for West and East African lineages of Rift Valley fever virus. Parasites & Vectors, 9:94

Tambo, E., Olalubi, O.A. & Sacko, M. (2016). Rift valley fever epidemic in Niger near border with Mali. Infectious Diseases, 16 (12): P1319-1320.

WHO: Disease Outbreak News, 29 September 2016. Rift Valley Fever in Niger and unpublished WHO Situation Reports.

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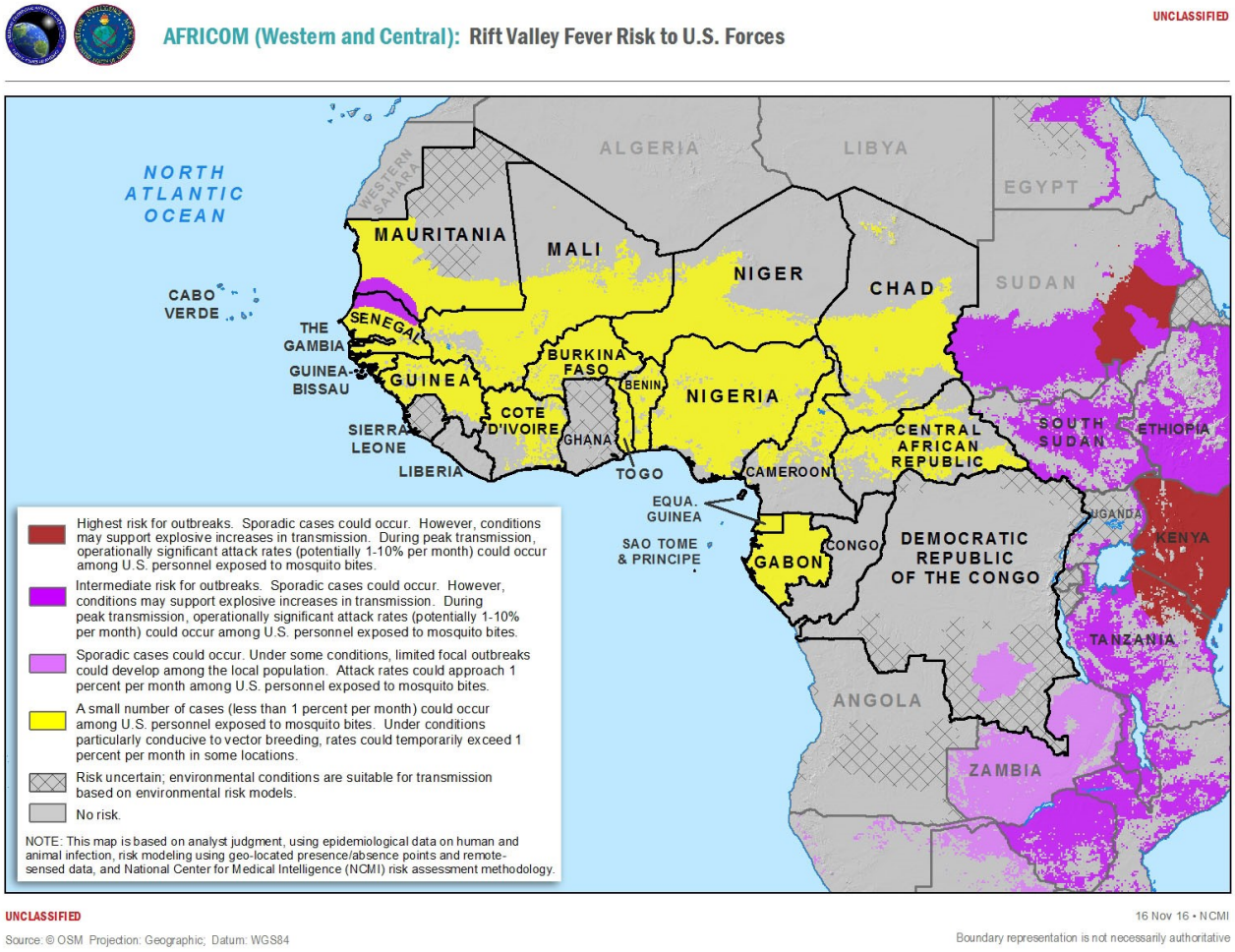
Rift Valley Fever Virus



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Bancroftian filariasis

I. Disease Background: Bancroftian filariasis is caused by the nematode *Wuchereria bancrofti*, which normally resides in the lymphatic system of infected humans. After 8 to 12 months, adult female worms release thousands of microfilariae into the circulatory system. Females continue to produce microfilariae over the next 15 to 18 years. Many individuals are asymptomatic in the early stages of infection. The disease develops slowly, with recurrent episodes of fever and inflammation of the lymph glands. Microfilariae can obstruct the lymphatic system, causing the legs, breasts or scrotum to swell to grotesque proportions, a chronic condition known as elephantiasis. This occurs only after repeated infections. Death of numerous microfilariae resulting from drug therapy may cause severe immune reactions.

II. Military Impact and Historical Perspective: Microfilariae of *W. bancrofti* were discovered in the blood of a patient in Brazil in 1866. This was the first discovery of a pathogen that is transmitted by insects. Over 70 million people worldwide are estimated to be infected by *W. bancrofti*, resulting in serious economic costs to developing countries. The long incubation period and requirement for multiple infections over a long period of time before the appearance of clinical symptoms render chronic Bancroftian filariasis of little medical significance to military operations. However, military personnel moving into an endemic area from one that is free from filariasis may develop symptoms such as swelling of the lymph glands, headache and fever many months before larvae become mature. American military forces in the Samoan-Ellice-Wallis Islands from 1942 to 1944 rapidly developed swollen lymph glands and extremities following repeated exposure to infected mosquitoes. Acute filariasis is the primary military concern, because its symptoms develop fairly rapidly and may be severe enough to cause removal of troops from their duties. In addition, observing local members of the population with grotesque deformities caused by chronic infection can have an adverse psychological impact. Medical personnel should be aware that troops with brief exposure to infection are often not diagnosed until after they return from deployments.

III. Transmission Cycle(s): Microfilariae circulating in human blood are ingested by mosquitoes and undergo several days of development before the vector can transmit infective stages of the nematode. Infective parasites enter the bloodstream directly during a mosquito bite. A few nematode larvae are deposited on the skin and can enter the host through skin abrasions. In humans, larvae undergo development to adults that produce microfilariae for many years. Over most of its geographic range, *W. bancrofti* microfilariae usually exhibit pronounced nocturnal periodicity and consequently are ingested by night-biting mosquitoes. Peak abundance of microfilariae in the blood occurs between 23:00 and 03:00 hours. *Culex quinquefasciatus* is the most common urban vector. In rural areas, transmission is maintained mainly by *Anopheles gambiae* s.l. and *An. funestus.* There are no known animal reservoirs of Bancroftian filariasis. Seasonal distribution generally coincides with rainy periods in endemic areas.

IV. Additional Resources:

CDC Background Lymphatic filariasis

WHO Background Lymphatic filariasis

Agi, P.I. & Ebenezer, A. (2009). Observations on Filarial Infection in Amassoma Community in the Niger Delta, Nigeria. Journal of Applied Sciences and Environmental Management, 13(1): 15-19.

de Souza, D.K., Koudou, B., Kelly-Hope, L.A., et al. (2012). Diversity and transmission competence in lymphatic filariasis vectors in West Africa, and the implications for accelerated elimination of *Anopheles*-transmitted filariasis. Parasites & Vectors, 5 (259).

Koudou, B.G., de Souza, D.K., Biritwum, N.-K., et al. (2018). Elimination of lymphatic filariasis in west African urban areas: Is implementation of mass drug administration necessary? The Lancet Infectious Diseases, 18(6): PE214-E220. doi: http://dx.doi.org/10.1016/ S1473-3099(18)30069-0

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Leishmaniasis

I. Disease Background: This potentially disfiguring and sometimes fatal disease is caused by infection with protozoan parasites of the genus *Leishmania.* Transmission results from bites of infected phlebotomine sand flies. All vectors of leishmaniasis in the Old World are in the sand fly genus *Phlebotomus*. Incubation in humans may take as little as ten days, or more than six months. Symptoms include ulcerative cutaneous lesions (cutaneous leishmaniasis or CL), lesions in the mucosal areas of the mouth and/or nose (mucocutaneous leishmaniasis or MCL), and internal pathological manifestations resulting in fever, swollen lymph glands, anemia, enlargement of the liver and spleen, and progressive emaciation and weakness (visceral leishmaniasis or VL). In Africa, both CL and VL are important public health problems. CL (Baghdad boil, Jericho boil, Oriental sore), caused by infection with *Leishmania major* or *Le. tropica*, typically appears as a nonhealing ulcer. The lesion usually develops within weeks or months after a sand fly bite and slowly evolves from a papule to a nodule to an ulcer. Cutaneous lesions may resolve quickly (2-3 months) without treatment or they may become chronic (lasting months to years) and will seldom heal without treatment. Scarring is associated with healing. In endemic areas, such scars are common among both rural and urban populations. Life-long immunity to the infecting *Leishmania* species normally results. VL (Kala-azar, Dum Dum fever), is the most severe form of leishmaniasis, with as much as 95% mortality in untreated cases. It is a chronic disease and, without treatment, is marked by fever (2 daily peaks), weakness and, as the parasites invade internal organs, weight loss coupled with enlargement of spleen and liver that may resemble severe malnutrition. It should be noted that cutaneous lesions may also be seen in human visceral leishmaniasis cases, but the chronic visceralizing nature of the disease is the main concern. In the Old World, VL is usually attributed to *L. donovani* or *L. infantum*. Viscerotropic *L. tropica* has also been reported and was described in veterans of the Persian Gulf war. The incubation period for VL is usually 4 to 6 months but may be as short as 10 days or as long as two years. By the time the disease is diagnosed, patients have usually forgotten any contact with sand flies. In endemic regions it is a disease of the young and old, who succumb to it disproportionately. Epidemics of VL often follow conditions of severe drought, famine or disruption of native populations by wars that produce large numbers of refugees.

II. Military Impact and Historical Perspective: Although not a war stopper, leishmaniasis is a persistent health threat to U.S. military personnel because troops deploy or conduct military exercises in locations where the disease is endemic. The overall potential for this disease to compromise mission objectives is significant. Soldiers exposed to sand fly bites while deployed to the region are susceptible to infection with *Leishmania.* Immunity among US military personnel is essentially nonexistent, and recovery from CL does not confer immunity to VL. In the Karum River Valley of Iraq, US forces suffered 630 cases of the disease in a 3-month period during WWII. During the 1967 "Six Day War," Israeli soldiers camped near Jericho in the Jordan Valley suffered a 50% attack rate of *Le. major*. In the northern Sinai desert, 113 cases of *Le. major* were reported from Multinational Forces and observers from 1973 through 1991. In 1990-91, twenty cases of CL due mainly to *Le. major* and 12 cases of VL due to *Le. tropica* were diagnosed when 697,000 allied soldiers were deployed to the Arabian Peninsula during Operations Desert Shield and Storm. Even though no fatalities were associated with leishmaniasis in this deployment, new lessons were learned that could affect future military deployments. Before the Persian Gulf War, eastern Saudi Arabia was not known to be endemic for visceral leishmaniasis and *L. tropica* was not convincingly shown to produce visceral disease. More importantly, the potential for leishmaniasis to cause intransigent post-deployment diagnostic problems and threaten blood supplies had not been anticipated. Returnees from the Persian Gulf War were barred from donating blood for up to two years, severely impacting blood supplies. Infection with *Leishmania* was even listed as one of the causative agents of Persian Gulf War syndrome, but scientific evidence for this association is lacking. Diagnosis of leishmaniasis is difficult at best, and providing proper care for service members who may have been exposed or infected is a long, costly and complex process. The first case of CL known to West Africa was reported from Niger in 1911 (Stevenel, 1911), and subsequent reports have shown CL in southern, central, and western Niger including in and around Niamey, however, occurrence is most likely nation-wide. Cases of CL are most likely underreported in Niger as no cases have been reported since 1990 when 64 cases were reported from 1984-1990. VL has been found in the Air Massif range, Agadez Department in the northwest, and few cases have been reported in Zinder Department (IAMAT, 2019). VL is thought to have a much wider distribution and prevalence throughout the country than figures show. The risk from both VL and CL is intermediate year round in Niger (NCMI, 2019).

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Leishmaniasis

III. Transmission Cycle(s): *Leishmania donovani* and *L. major* are the primary parasites causing VL and CL in West Africa, respectively. VL due to *L. infatum* may also be present in the northern deserts of Niger. While there is some obscurity when it comes to the reservoirs of this region, domestic dogs, rodents, and other wild carnivores and mammals have been seen as reservoirs in the region. Female *Phlebotomus sp.* acquire infections while feeding on their rodent hosts. Amastigotes (the mammalian form of the Leishmania parasite) ingested with the bloodmeal transform to a flagellated promastigote form within the gut of the female fly. In addition to a bloodmeal, the female fly seeks and consumes sugar from the plants in the area during subsequent nocturnal flights. These sugars help maintain *Leishmania* infections in the flies. Promastigotes multiply in the gut of the sand fly within the bloodmeal and undergo development to an infective form called the metacyclic promastigote. By the time the bloodmeal is digested and the fly is ready to lay its eggs, infective metacyclic promastigotes are ready to be transmitted to the next vertebrate host when the sand fly feeds again. In *Le. major* foci, where the principal reservoirs are colonial rodents, humans are considered accidental or incidental hosts, becoming infected when their habitat overlaps that of the rodent host. CL and VL are scarce in urban areas but more prevalent in rural regions.

IV. Additional Resources:

CDC Background Leishmaniasis

WHO Background Leishmaniasis

WHO Leishmaniasis Resources

IAMAT: Leishmaniasis

Jacobson, R.L. (2011). Leishmaniasis in an era of conflict in the Middle East. Vector-Borne and Zoonotic Diseases: 11(3): 247-258.

Develoux, M., Blanc, L., Garba, S., et al. (1990). Cutaneous leishmaniasis in Niger. The American Society of Tropical Medicine and Hygiene, 43(1): 29-30.

Boakye, D.A., Wilson, M.D. & Kweku, M. (2005). A Review of Leishmaniasis in West Africa. Ghana Medical Journal, 39(3): 94-97.

Kone, A.K., Niare, D.S., Piarroux, M., et al. (2019). Visceral Leishmaniasis in West Africa: Clinical Characteristics, Vectors, and Reservoirs. Journal of Parasitology Research, Article ID: 9282690.

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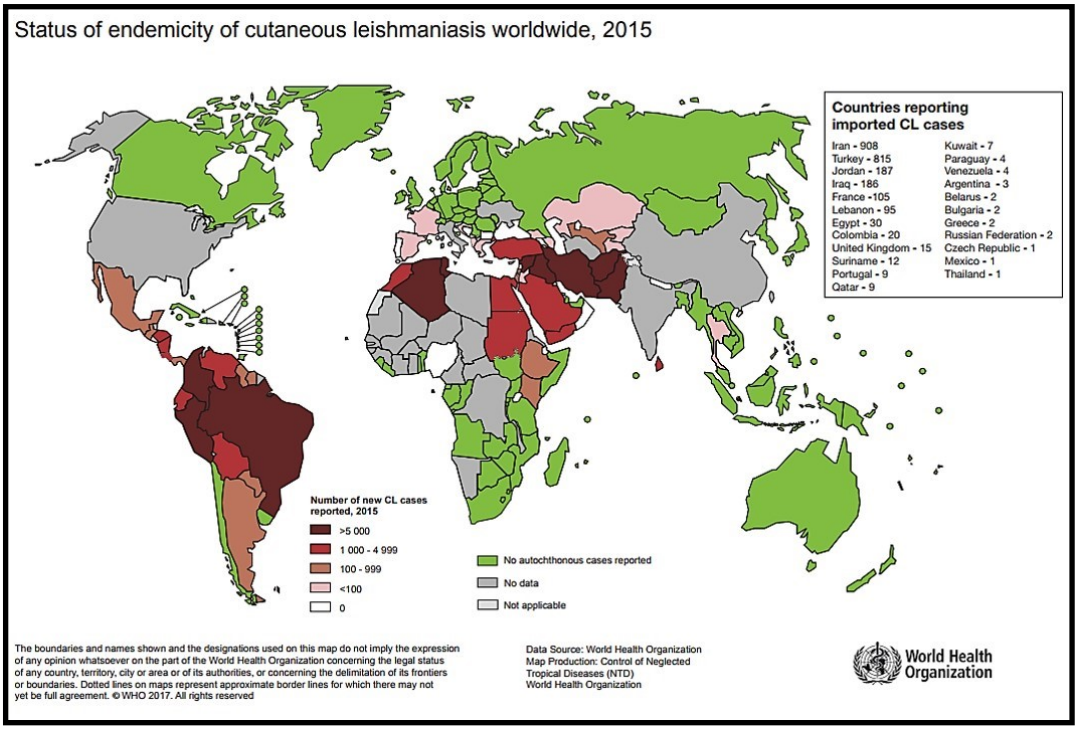
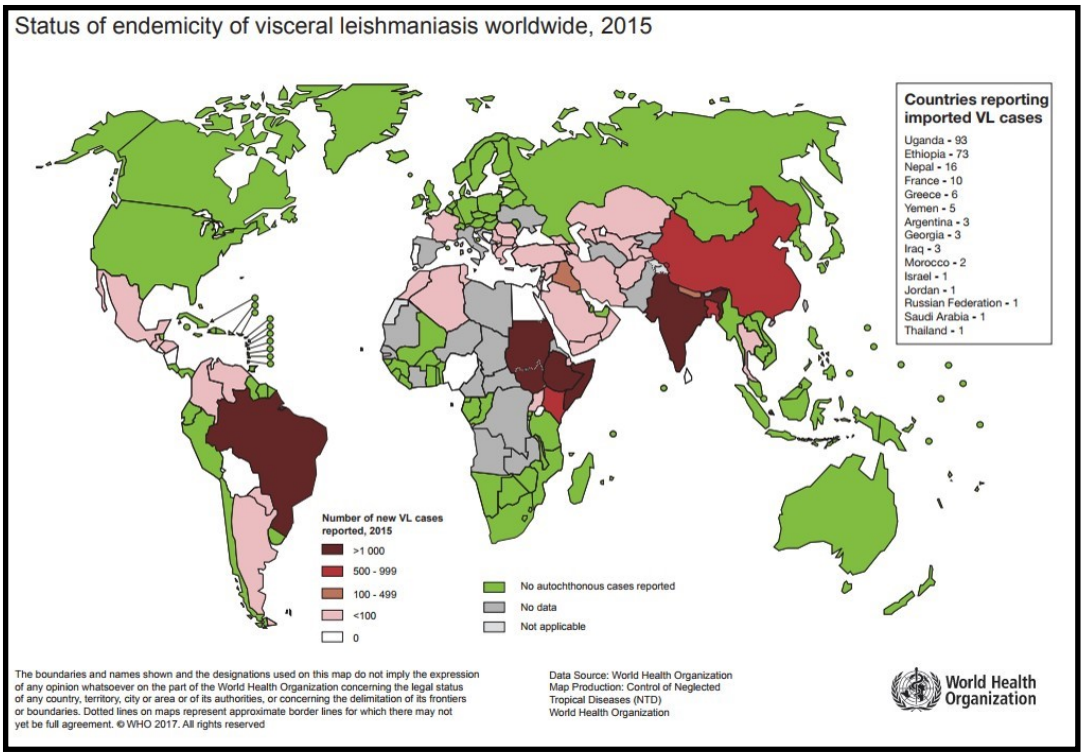
Leishmaniasis

Disease Distribution





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Boutonneuse Fever

I. Disease Background: (Mediterranean tick fever, Mediterranean spotted fever, Marseilles fever, African tick typhus, Kenya tick typhus, India tick typhus) This tick-borne typhus is a mild to severe illness lasting a few days to 2 weeks and caused by *Rickettsia conorii* and closely related organisms. Different strains of *R. conorii* have been isolated from ticks and humans. The common name of this disease comes from the button-like lesions, 2 to 5 mm in diameter, that develop at tick attachment sites. With antibiotic treatment, fever lasts no more than 2 days. The case fatality rate is very low, even without treatment.

II. Military Impact and Historical Perspective: Boutonneuse fever has not significantly interfered with military operations in the past. Sporadic cases among combat troops can be expected in limited geographic areas. The severity of illness depends on the strain of *R. conorii* contracted. Because the spotted fevers are regional diseases, military medical personnel newly assigned to an area may be unfamiliar with them and diagnosis may be delayed. The risk of Boutonneuse fever to U.S. personnel is low year round in primarily rural regions (NCMI, 2019).

III. Transmission Cycle(s): The disease is maintained in nature by transovarial passage of the pathogen in ticks, primarily the brown dog tick, *Rhipicephalus sanguineus*, although almost any *Ixodes* sp. may harbor the pathogen. Enzootic infection in dogs, rodents and other animals is usually subclinical. Transmission to humans is by bite of infected ticks. Contamination of breaks in the skin or mucous membranes with crushed tissues or feces of infected ticks can also lead to infection.

IV. Additional Resources:

CDC Background Rickettsial (Spotted & Typhus Fevers) & Related Infections

Okulicz, J.F. 2016. Boutonneuse Fever. Medscape.com

Rovery, C., Brouqui, P. & Raoult, D.. 2008. Questions on Mediterranean spotted fever a century after its discovery. Emerging Infectious Diseases. 14(9): 1360-1367.

Julves, J., Michault, A., & Kerdelhue, C. (1997). [Serological study of rickettsia infections in Niamey, Niger]. Med Trop (Mars), 57(2): 153-6.

Mouffok, N., Parola, P., Lepidi, H. & Raoult, D. (2009). Mediterranean spotted fever in Algeria – new trends. International Journal of Infectious Diseases, 13(2): 227-235.

Query Fever (Q fever)

I. Disease Background: This is an acute, self-limiting, febrile rickettsial disease caused by *Coxiella burnetii*. Onset may be sudden with chills, headache and weakness. Pneumonia is the most serious complication. There is considerable variation in severity and duration of illness. Infections may be unapparent or present as a nonspecific fever of unknown origin. The case fatality rate in untreated acute cases is less than 1%.

II. Military Impact and Historical Perspective: *Coxiella burnetii* was originally described from Australia in 1937. In ensuing years, *C. burnetii* was found to have a worldwide distribution and a complex ecology and epidemiology. Cases of Q fever occurred in US troops during World War I, and the disease also caused epidemics in the armies fighting during World War II. Three cases of Q fever were recorded in US military personnel during the Persian Gulf War.

III. Transmission Cycle(s): In nature there are two cycles of infection with *C. burnetii*. One involves arthropods, especially ticks, and a variety of wild vertebrates. The other cycle is maintained among domestic animals. Although humans are rarely, if ever, infected by ticks, arthropods may transmit infection to domestic animals, especially sheep and cattle. Domestic animals have unapparent infections but shed large quantities of infectious organisms in their urine, milk, feces, and especially their placental products. Because *C. burnetii* is highly resistant to desiccation, light and extremes of temperature, infectious organisms become aerosolized, causing widespread outbreaks in humans and other animals, often at a great distance from place of origin. Dust in sheep or cattle sheds may become heavily contaminated. Once established, animal-to-animal spread of *C. burnetii* is maintained primarily through airborne transmission. Outbreaks of Q fever in humans have been traced to consumption of infected dairy products, contact with contaminated wool or hides, infected straw, and infected animal feces. *C. burnetii* may enter through minor abrasions of the skin or the mucous membranes. Although rare, human-to-human transmission of Q fever has occurred.

IV. Additional Resources:

CDC Background Q Fever

Maurin, M. & Raoult, D. (1999). Q Fever. Clinical Microbiology Review. 12(4): 518-553.

Steinmann, P., Bonfoh, B., Peter, O., et al. (2005). Seroprevalence of Q-fever in febrile individuals in Mali. Tropical Medicine and International Health, 10(6): 612-617.

Kobbe, R., Kramme, S., Kreuels, B., et al. (2008). Q Fever in Young Children, Ghana. Emerging Infectious Diseases, 14(2): 344-346.

Trypanosomiasis (Sleeping Sickness)

I. Disease Background: Trypanosomiasis, or sleeping sickness, is a parasitic disease transmitted by tsetse flies of the genus *Glossina.* The protozoan hemoflagellate parasites, *Trypanosoma brucei gambiense* and *T. b. rhodesiense*, are the infectious agents which causes two stages of symptoms. The first stage, the haemolymphatic stage, has fever, headaches, joint pains, and itching as common symptoms while trypanosomes begin to accumulate and spread into the subcutaneous tissues, blood and lymph. As the parasites move across the blood-brain barrier, the disease enters its second stage, the neurological or meningo-encephalitic stage, and the central nervous system is infected. This stage sees confusion, poor coordination, sensory disturbances, changes of behavior and a disturbance of the sleep cycle as common symptoms. When infected by *T. b. rhodesiense* sleeping sickness is known as East African sleeping sickness, which progresses rapidly leading to coma and ultimately death typically within months. *T. b. gambiense* infections cause West African sleeping sickness, which progress more slowly and usually kills within three years. A characteristic lesion called a trypanosomal chancre often develops at the site of the bite. A small raised papule develops around five days post bite and quickly enlarges and becomes surrounded by an erythematous tissue reaction. Treatments for the different parasites and different stages are different and must be started as soon as possible so as to prevent the complications associated with the neurological stage from beginning. There is no vaccine for Trypanosomiasis. A proper diagnosis resides in the ability to observe the parasites in body fluids or tissue by microscopy, and an examination of cerebrospinal fluid to determine the correct stage.

II. Military Impact and Historical Perspective: Sleeping sickness has been known since the slave trade was active, but outbreaks were unknown until the 20th century. Niger is one of 36 countries considered endemic, however, there have not been any cases reported in the last 20 years. Due to the lack of reported cases, Niger is also one out of 6 countries listed as endemic who have not received any support through WHO or other NGO's. The country conducts no regular surveillance, so a clarification of its epidemiological outlook is deserved (Simarro, 2011). In fact, only 10% of the 60 million people at risk across Africa are in locations where surveillance occurs. Trypanosomiasis is believed to have spread throughout West Africa, in part, due to the French colonial policy as large numbers of laborers were resettled throughout the region bringing parasites along with them. Between 1932 and 1953, nearly 550,000 cases of human African Trypanosomiasis were reported from all of West Africa with foci throughout the region. Nearly 2,000 cases came from Niger during this time period as well (Courtin, 2008). Sleeping sickness cases significantly declined through the next 20 years due to control efforts, however, since the 1970s, the disease has made a comeback in the coastal countries of the region. Imported cases have been seen in Mali and nearby countries as well. Overall, the extent of Trypanosomiasis in West Africa today is unknown due to poor surveillance and control efforts, however, the foci in Niger is thought to be inactive (Courtin, 2008).

III. Transmission Cycle(s): Sleeping sickness is a disease transmitted primarily through the bite of an infected tsetse fly (*Glossina sp.*), however, there are a few other methods of human transmission: vertical transmission (human mother-to-child), sexual transmission and infection due to contaminated needle usage. Various animals, domestic and wild (higher infection rates in wild animals) can be reservoirs for trypanosomes (particularly of *T.b. rhodesiense*). *T.B. gambiense* can infect these animals as well but to a much lesser extent. *G. tachinoides* and *G. morsitans submorsitans* are thought to be the major historical vectors of Trypanosomiasis in Niger. Post blood meal, the *Trypanosoma sp.* migrate from the hindgut to the salivary glands where they transform into trypanosomes capable of being inoculated into a new host in the fly's next blood meal. Once these trypanosomes have been injected into a herd it's possible for the disease to be mechanically spread through other biting flies when they feed on more than one host in a short period of time.

IV. Additional Resources:

CDC Background Sleeping Sickness

WHO Background Sleeping Sickness

WHO Global Alert and Response

Buscher, P., Bart, J.M., Boelaert, M., et al. (2018). Do Cryptic Reservoirs Threaten Gambiense-Sleeping Sickness Elimination?. Trends in Parasitology, Vol 34(3): 197-207.

Courtin, F., Jamonneau, V., Duvallet, G., et al. (2008). Sleeping sickness in West Africa (1906-2006): changes in spatial repartition and lessons from the past. Tropical Medicine and International Health, 13(3): 334-344.

Koffi, M., De Meeus, T., Bucheton, B., et al. (2009). Population genetics of *Trypanosoma brucei gambiense*, the agent of sleeping sickness in Western Africa. PNAS, 106(1): 209-214.

Simarro, P.P., Cecchi, G., Paone, M., et al. (2010). The Atlas of human African trypanosomiasis: a contribution to global mapping of neglected tropical diseases. International Journal of Health Geographics, 9:57.

Isaac, C., Ciosi, M., Hamilton, A., et al. (2016). Molecular identification of different trypanosome species and subspecies in tsetse flies of northern Nigeria. Parasites & Vectors, 9:301.

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Crimean-Congo Hemorrhagic Fever (CCHF)

I. Disease Background: CCHF is a zoonotic disease caused by a tick-borne virus of the family *Bunyaviridae*. The disease is characterized by febrile illness with headache, muscle pain and rash, frequently followed by a hemorrhagic state with hepatitis. The mortality rate can exceed 30%. The incubation period ranges from 3 to 10 days. CCHF may be confused clinically with other hemorrhagic infectious diseases.

II. Military Impact and Historical Perspective: Descriptions of a disease compatible with CCHF can be traced back to antiquity in eastern Europe and Asia. CCHF was first described in soldiers and peasants bitten by ticks of the genus *Hyalomma* while working and sleeping outdoors in the Crimean peninsula in 1944. The virus was first isolated in 1967. Since there are no available treatment regiments of proven value and recovery from CCHF can be very protracted, military personnel with CCHF require significant medical resources. Seroprevalence of CCHF in Niger has been reported in camels, sheep, goats, cattle and other small ruminants. The potential risk of CCHF to U.S. personnel is intermediate year round primarily in rural locations with close association to livestock (NCMI, 2019).

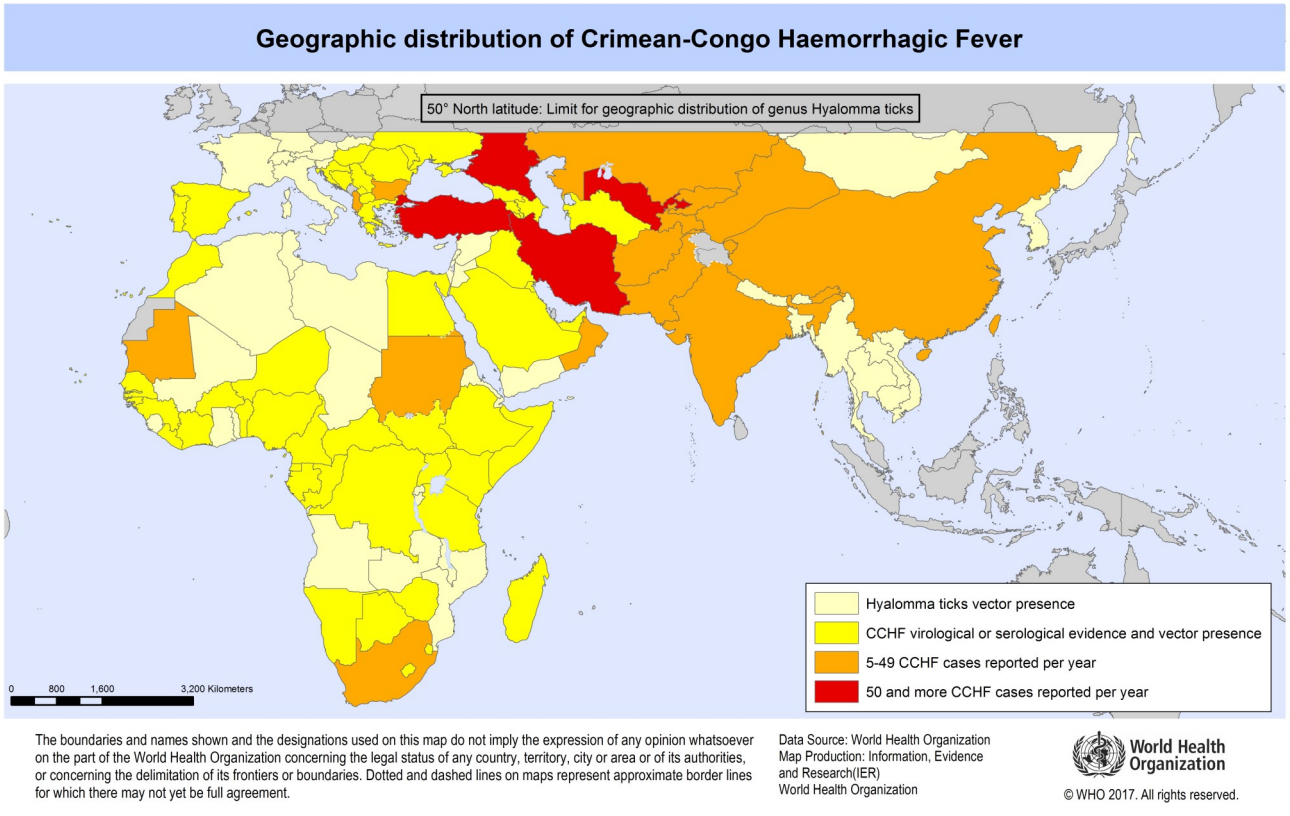
III. Transmission Cycle(s): CCHF virus has been isolated from at least 30 species of ticks. From experimental evidence it appears that many species of ticks are capable of transmitting the virus, but members of the genus *Hyalomma* are the most efficient vectors. The aggressive host-seeking behavior of adult hyalommines makes these ticks ideal vectors. The highest prevalence of antibodies in wild and domestic reservoirs has been found in arid areas where *Hyalomma* sp. are common. Antibodies to CCHF virus are widespread in large wild and domestic herbivores. Domestic ruminants generally acquire infection early in life. Viremia in livestock is short-lived and of low intensity. Antibodies or virus have been found in a variety of small mammals, including hares, hedgehogs and rodents. Transovarial transmission of virus in vector ticks is an important reservoir mechanism. Humans acquire CCHF virus from tick bites, from contamination of broken skin or mucous membranes with crushed tissues or feces of infected ticks, or from contact with blood or other tissues of infected animals. CCHF virus is highly infectious, and nosocomial infection of medical workers has been important in many outbreaks. CCHF virus loses infectivity shortly after the death of an infected host. There is no indication that consumption of meat processed according to normal health regulations constitutes a hazard.

IV. Additional Resources:

CDC Background CCHF

WHO Background CCHF

Mariner J.C., Morrill J., Ksiazek T.G. (1995). Antibodies to hemorrhagic fever viruses in domestic livestock in Niger: Rift Valley fever and Crimean-Congo hemorrhagic fever. The American Journal of Tropical Medicine and Hygiene, 53: 217– 21



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African Tick Bite Fever

I. Disease Background: African Tick Bite Fever (ATBF) is a tick-borne spotted fever caused by *Rickettsia africae* in West Africa. ATBF has a typical incubation period of 5-7 days but could last as long as 10 days. The disease is often marked by an inoculation eschar at the attachment site of the tick, and is followed within 2 weeks by symptoms such as fever, headache, myalgia, rash, and lymphadenopathy. Immunofluorescence assays or DNA detection through PCR's of whole blood, eschar swabs, or skin biopsies accurately identify the bacterial agent. ATBF is typically a fairly mild and self-limited febrile illness although some cases can require hospitalization. Oral doxycycline is the typical therapeutic to combat ATBF, however, other antibiotics have been used but their efficacy is under question.

II. Military Impact and Historical Perspective: Over 350 cases attributed to travel have been reported in Europe, Australia, North America, South America, and Japan with the majority of these cases having been acquired in South Africa (Chmielewski, 2013). While the exact prevalence of *R. africae* is unclear there have been studies showing seroprevalences of spotted fever group rickettsiae anywhere from 30-80% in sub-Saharan Africa.

III. Transmission Cycle(s): *Amblyomma variegatum* and other amblyommids rarely feed on humans, but their larvae and nymphs can be abundant and aggressive vectors. Due to the nature of these *Amblyomma sp.,* cattle are one of the most important domestic reservoirs of ATBF and other ruminants have proven to be important reservoirs as well.

IV. Additional Resources:

CDC: Tick Borne Diseases Abroad

Mediannikov, O., Trape, J.-F., Diatta, G., et al. (2010). *Rickettsia africae*, Western Africa. Emerging Infectious Diseases, 16 (3): 571-573.

Parola, P., Inokuma, H., Camicas, J.-L., et al. (2001). Detection and Identification of Spotted Fever Group *Rickettsiae* and *Ehrlichae* in African Ticks. Emerging Infectious Diseases, 7(6

Owen, C.E., Bahrami, S., Malone, J.C., et al. (2006). African Tick Bite Fever: A Not-So-Uncommon Illness in International Travelers. Arch Dermatol, 142(10): 1312-1314.

Relapsing Fever (Tick-borne)

I. Disease Background: This is a systemic spirochetal disease characterized by periods of fever alternating with afebrile periods. The number of relapses varies from 1 to 10 or more. The severity of illness decreases with each relapse. The duration of tick-borne relapsing fever is usually longer than the closely related louse-borne relapsing fever. A number of species of *Borrelia* are responsible for the disease. The taxonomy of the pathogen is complex. The close vector-spirochete relationship has led to the definition of most spirochete species by the tick vector. There is great strain variation among tick-borne *Borrelia*, and a single strain can give rise to many serotypes. Some authorities view all species as tick-adapted strains of the louse-borne relapsing fever spirochete, *B. recurrentis*.

II. Military Impact and Historical Perspective: Although clinical symptoms of tick-borne relapsing fever can be severe, impact on military personnel would be minimal due to low incidence of the disease.

III. Transmission Cycle(s): Soft ticks of the genus *Ornithodoros* transmit tick-borne relapsing fever. Infection is transmitted from human to human, animal to animal, or from animal to man by the bite of infective ticks. Rodents are sources of infection for ticks, although ticks are more important as long-term reservoirs. The pathogen has been maintained naturally in some species of ticks for years by transovarial transmission. The rate of transovarial transmission varies greatly among tick species. Ticks of both sexes and all active stages transmit the pathogen by bite or by infectious fluids exuded from pores in the basal leg segments. Spirochetes can pass into bite wounds or penetrate unbroken skin. Exposure to infected blood of patients can cause infections in medical personnel.

IV. Additional Resources:

CDC Background Relapsing Fever

Dworkin, M.S., Schwan, T.G., Anderson, D.E. Jr & Borchardt, S.M. 2008. Tick-Borne Relapsing Fever. Infectious Disease Clinics of North America. 22(3): 449-468.

Trape, J.-F., Diatta, G., Arnathau, C., et al. (2013). The Epidemiology and Geographic Distribution of Relapsing Fever Borreliosis in West and North Africa, with a Review of the Ornithodoros erraticus Complex (Acari: Ixodida). PLoS ONE, 8(11): e78473

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Onchocerciasis (River Blindness)

I. Disease Background: This is a chronic, nonfatal disease in which adult worms form fibrous nodules in subcutaneous tissues. Adult female worms can live for 15 years and produce thousands of microfilariae that migrate through the skin, causing disfiguring skin lesions. Microfilariae invade other tissues and organs and may reach the eye, where their invasion and subsequent death cause visual disturbances and blindness. The parasite is a filarial nematode worm, *Onchocerca volvulus*. A related species, *O. fasciata*, occurs in camels but does not infect humans.

II. Military Impact and Historical Perspective: Onchocerciasis has had a devastating impact on villages in the savanna area of West Africa. In many places over 10% of the population is blind. Because of limited exposure, the impact of onchocerciasis would be insignificant during most military operations. The severity of disease depends on cumulative effects of repeated infection that could result in long-term health problems for continuously exposed troops. Knowledge of this could impact troop morale during an operation. Prolonged infection in an endemic area would be required to develop clinically severe disease. After infection, larvae grow into adult worms over a period of months. Microfilariae are found in the skin a year or more after the infective bite, which is usually long after military personnel have left an endemic area.

III. Transmission Cycle(s): Man is the definitive host in which *O. volvulus* multiplies. Microfilariae in human skin are ingested by vector black flies when they suck blood. In Africa, vectors are members of the *Simulium damnosum* complex. The microfilariae transform within the black fly to an infective stage that enters the human host when the fly takes subsequent blood meals. This period of development requires 7 to 14 days. Man is also the reservoir host. Onchocerciasis is not considered a zoonosis, although natural infections have been found in a spider monkey in Guatemala and a gorilla in the Congo. Chimpanzees can be infected in the laboratory.

IV. Additional Resources:

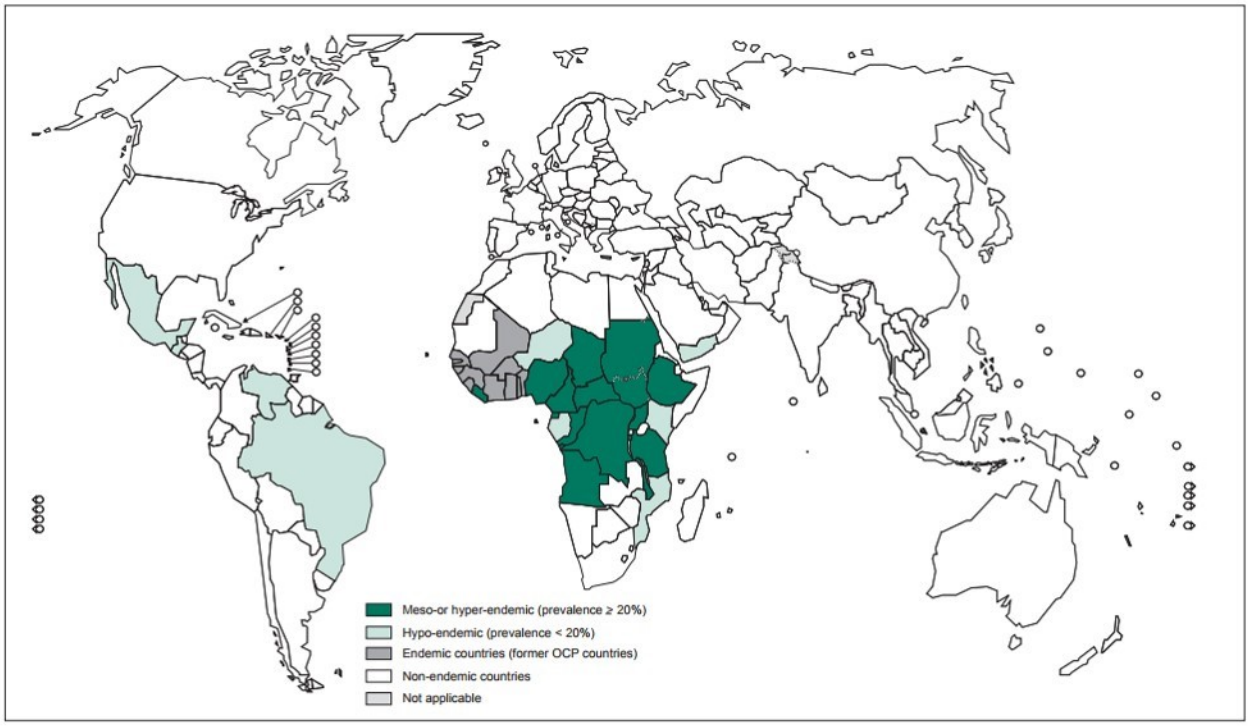
CDC Background Onchocerciasis

WHO Background Onchocerciasis

Routledge, I., Walker, M., Cheke, R.A., Bhatt, S., Nkot, P.B., Matthewsw, G.A., Baleguel, D., Dobson, H.M., Wiles, T.L. and Basanez, M.G. (2018). Modelling the impact of larviciding on the population dynamics and biting rates of *Simulium damnosum* (*s.l.*): implications for vector control as a complementary strategy for onchocerciasis elimination in Africa. Parasites & Vectors, 11:316.

Remme, J.H.F. (1989). The epidemiology and control of onchocerciasis in West-Africa.

Distribution of Onchocerciasis, Worldwide (2013)



Data Source: World Health Organization
Map Production: Control of Neglected Tropical Diseases (NTD)
World Health Organization

World Health Organization

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Mosquito Vector Species Profiles

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Aedes (*Fre.*) *vittatus* (Bigot, 1861)

Bionomics:

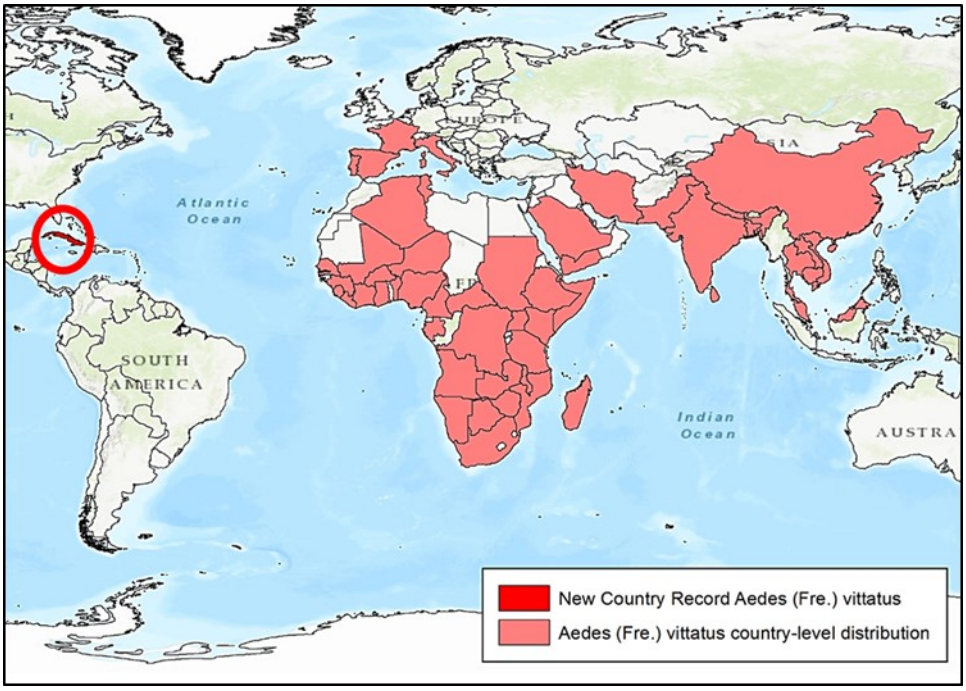
Aedes vittatus is a very environmentally tolerant species withstanding hot, dry climates while its eggs are capable of surviving desiccation for 10 weeks or more in the deserts of north Africa. Immatures have been found in natural habitats such as rock holes/pools, tree holes, and hoof prints. They've also adapted to utilize artificial containers in Delhi such as stone fountains, concrete drainage channels, etc. Adult *Aedes vittatus* are highly anthropophilic and have often been seen as the most abundant taxa caught in human landing collections (HLC) in some areas of Senegal.

Medical Importance:

An efficient vector of Zika, yellow fever, dengue, and chikungunya. Pathogen screening has detected the following arboviruses, however, the vector capacity is unknown:

BBKV, ONNV, NRIV, PGAV, SFV

WRBU Catalog



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Aedes (*Stg.*) *aegypti* (Linnaeus, 1762)

Bionomics:

Ae. aegypti is the best studied mosquito worldwide. Primarily found in close association with humans, *Ae. aegypti* will use any and all natural and artificial containers as larval breeding sites, but is sensitive to competition with *Aedes albopictus* in these larval sites. Away from urban areas the species tends to favor pools in river beds, tree stumps, tree holes and natural containers. The species is highly anthropophilic and will readily enter houses to feed, but some populations have been found to be zoophilic.

Medical Importance:

Ae. aegypti is considered a primary vector of dengue fever, yellow fever, chikungunya and Zika viruses. Pathogen screening has detected the following arboviruses and parasites, however, the vector capacity is unknown:

AINOV, AHSV, BOZOV, BSQV, BUNV, CATUV, CHPV, CPV, CVV, EEEV, EHDV, GROV, HPV, ILHV, ITV, IRIV, JAPV, JEV, JOIV, KETV, KUNV, LACV, MAYV, MBGV, MCOV, MEBV, MELV, MTBV, MUCV, MVEV, NAVV, NEPV, NOLAV, NTAV, ORIV, ORUV, RESV, RVFV, SFV, SINV, TAHV, TSUV, TYUV, VEEV, VSIV, WARV, WNV, WSLV, YAOV, ZEGV, *Plasmodium gallinaceum, Plasmodium lophurae*

Biting Times:	06:00-18:00
Host Preference:	Primarily Anthropophilic
Feeding Behavior:	Exophagic and Endophagic
Resting Behavior:	Exophilic and Endophillic

WRBU Catalog

Dengue Vector Bionomics (Ritchie, S. 2014)

VectorBase

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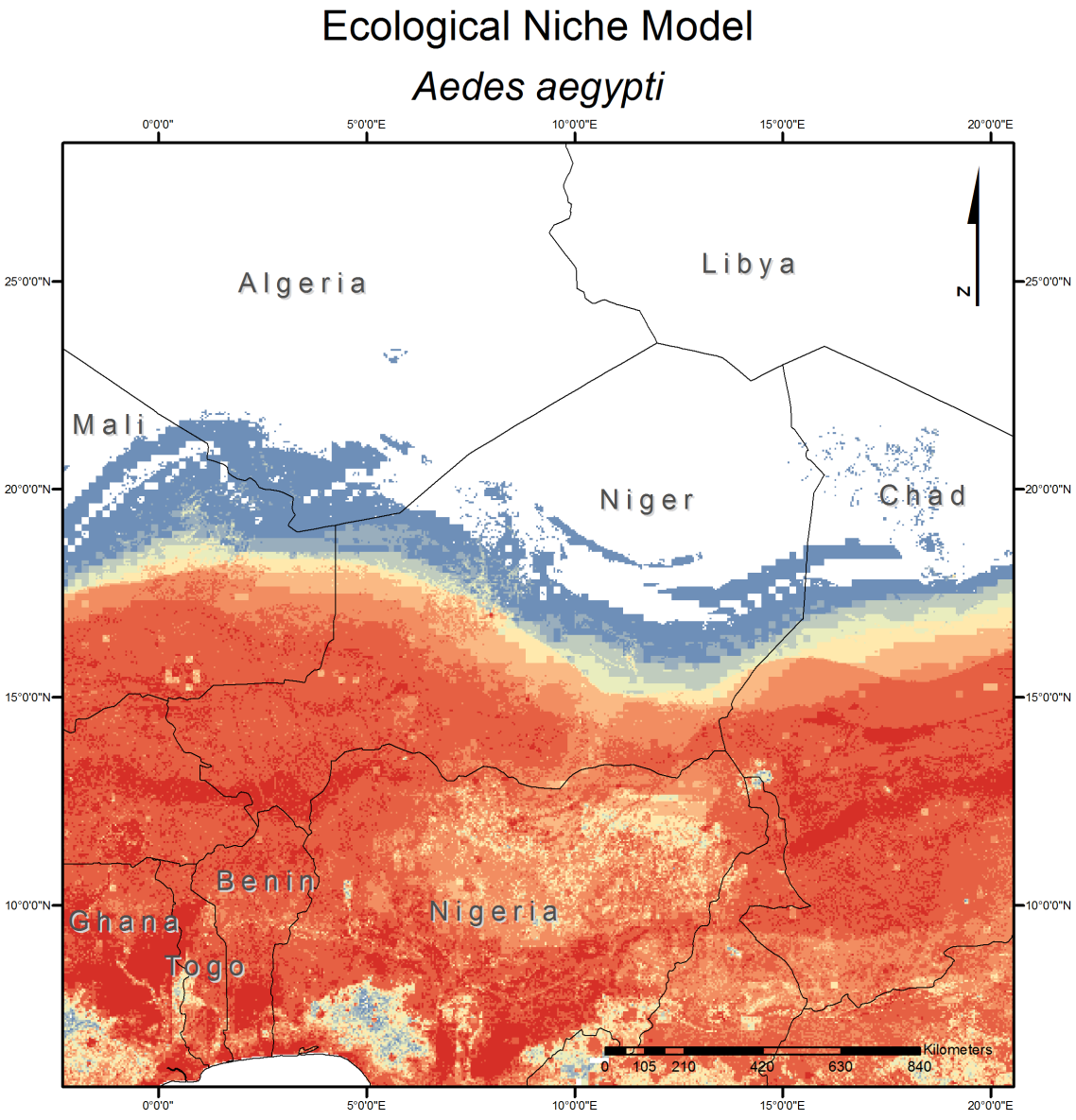
Aedes (*Stg.*) *aegypti* (Linnaeus, 1762)



Habitat suitability model using boosted regression trees (BRT). The map depicts the probability of occurrence (from 0 blue to 1 red) at a spatial resolution of 5 km x 5 km.
Models published at:
Kraemer, M. U., Sinka, M. E., Duda, K. A., Mylne, A. Q., Shearer, F. M., Barker, C. M., ... & Hendrickx, G. (2015). The global distribution of the arbovirus vectors Aedes aegypti and Ae. albopictus. elife, 4, e08347.

WRBU VectorMap

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Aedes (*Stg.*) *aegypti* (Linnaeus, 1762)

I. Vector Surveillance and Suppression: Landing rate counts provide a quick relative index of adult abundance. The number of mosquitoes that land on an individual within a short period of time, usually one minute, is recorded. Several indices (container, house, Breteau indices) have been devised to provide a relative measure of the larval populations of *Ae. aegypti*. Adult egg-laying activity can be monitored by using black oviposition cups. Control of dengue fever is contingent upon reducing or eliminating vector populations. Ground or aerial applications of insecticidal aerosols have been relied upon to reduce adult populations during epidemics of dengue. Many vector control specialists have questioned the efficacy of ultra-low volume (ULV) adulticiding. In some outbreaks of dengue fever, ULV dispersal of insecticides has had only modest impact on adult mosquito populations. *Ae. aegypti* is a domestic mosquito that frequently rests and feeds indoors and therefore is not readily exposed to aerosols. The sides of large storage containers should be scrubbed to remove eggs when water levels are low. Water should be stored in containers with tight-fitting lids to prevent access by mosquitoes. A layer of oil will prevent mosquito eggs from hatching and will kill the larvae. The elimination of breeding sources, such as old tires, flowerpots, and other artificial containers, is the most effective way to reduce mosquito populations and prevent dengue outbreaks. In Singapore, passage of sanitation laws and their strict enforcement to eliminate breeding sites reduced the house index for *Ae. aegypti* larvae from 25% to 1%. Proper disposal of trash, bottles and cans at military cantonments must be rigidly enforced. The individual soldier can best prevent infection by using personal protective measures during the day when *Ae. aegypti* mosquitoes are active. Wear permethrin-impregnated uniforms and use extended-duration DEET repellent on exposed skin surfaces. For more detailed information on control strategies for Aedes aegypti, see the AFPMB Technical Guide No. 47: *Aedes* Mosquito Vector Control.

II. Reported Insecticide Resistance:

Vontasa, J., Kioulos, E., Pavlidi, N., Morou, E., della Torre, A. & Ranson, H. Insecticide resistance in the major dengue vectors Aedes albopictus and Aedes aegypti. Pesticide Biochemistry and Physiology 104(2): 126-131.

III. Vector Identification:

Rueda, L.M. 2004. Pictorial keys for the identification of mosquitoes (Diptera: Culicidae) associated with dengue virus transmission. Zootaxa. 589. 1-60.

LUCID Pictorial Key to the Medically Important Mosquitoes of AFRICOM (WRBU)

IV. Additional Resources:

WHO (2016). Promising new tools to fight *Aedes* mosquitoes. Bulletin of the World Health Organization, 94:562-563.

Surtees, G. (1967). The Distribution, Density and Seasonal Prevalence of *Aedes aegypti* in West Africa. Bulletin of the World Health Organization, 36: 539-540.

Sissoko, F., Junnila, A., Traore, M.M., et al. (2019). Frequent sugar feeding behavior by *Aedes aegypti* in Bamako, Mali makes them ideal candidates for control with attractive toxic sugar baits (ATSB). PLoS ONE, 14(6): e0214170.

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Anopheles (*Cel.*) *arabiensis* Patton, 1905

Bionomics:

An. arabiensis larvae are found in relative short duration, sunlit water pools (3-5 weeks) with high turbidity and a lack of aquatic vegetation or surface film. Chosen breeding sites appear to be associated with cattle, the preferred host. Although primarily known to occur in dry-savannah type environments, *An. arabiensis* is also found in forested areas that have been recently disturbed or cleared. Biting and resting behavior of adult female *An. arabiensis* is known to be highly variable. Adults are known to be both anthropophilic and zoophilic depending on the availability of blood meals. This species is also known to modify resting behavior when in contact with some insecticides used during Indoor Residual Spraying (IRS) control measures. In west Africa, *An. arabiensis* populations are present throughout the year and many individuals may survive through the dry season.

Medical Importance:

An. arabiensis is a vector of malaria in west Africa.

Debalke, S., Habtewold, T., Duchateau, L. and Christophides, G.K. (2019). The effect of silencing immunity related genes on longevity in a naturally occurring *Anopheles arabiensis* mosquito population from southwest Ethiopia. Parasites & Vectors, 12: 174.

Wondwosen, B., Birgersson, G., Tekie, H., Torto, B., Ignell, R. and Hill, S.R. (2018). Sweet attraction: sugarcane pollen-associated volatiles attract gravid *Anopheles arabiensis*. Malaria Journal, 17:90.

Ndiath, M.O., Cailleau, A., Orlandi-Pradines, E., et al. (2015). Emerging knock-down resistance in *Anopheles arabiensis* populations of Dakar, Senegal: first evidence of a high prevalence of *kdr-e* mutation in West African urban area. Malaria Journal, 14:364.

WRBU Catalog

VectorBase

Biting Times:	19:00-03:00
Host Preference:	Primarily Zoophilic but known to be Anthropophilic on occasion
Feeding Behavior:	Exophagic
Resting Behavior:	Primarily Exophillic but known to be Endophillic on occasion

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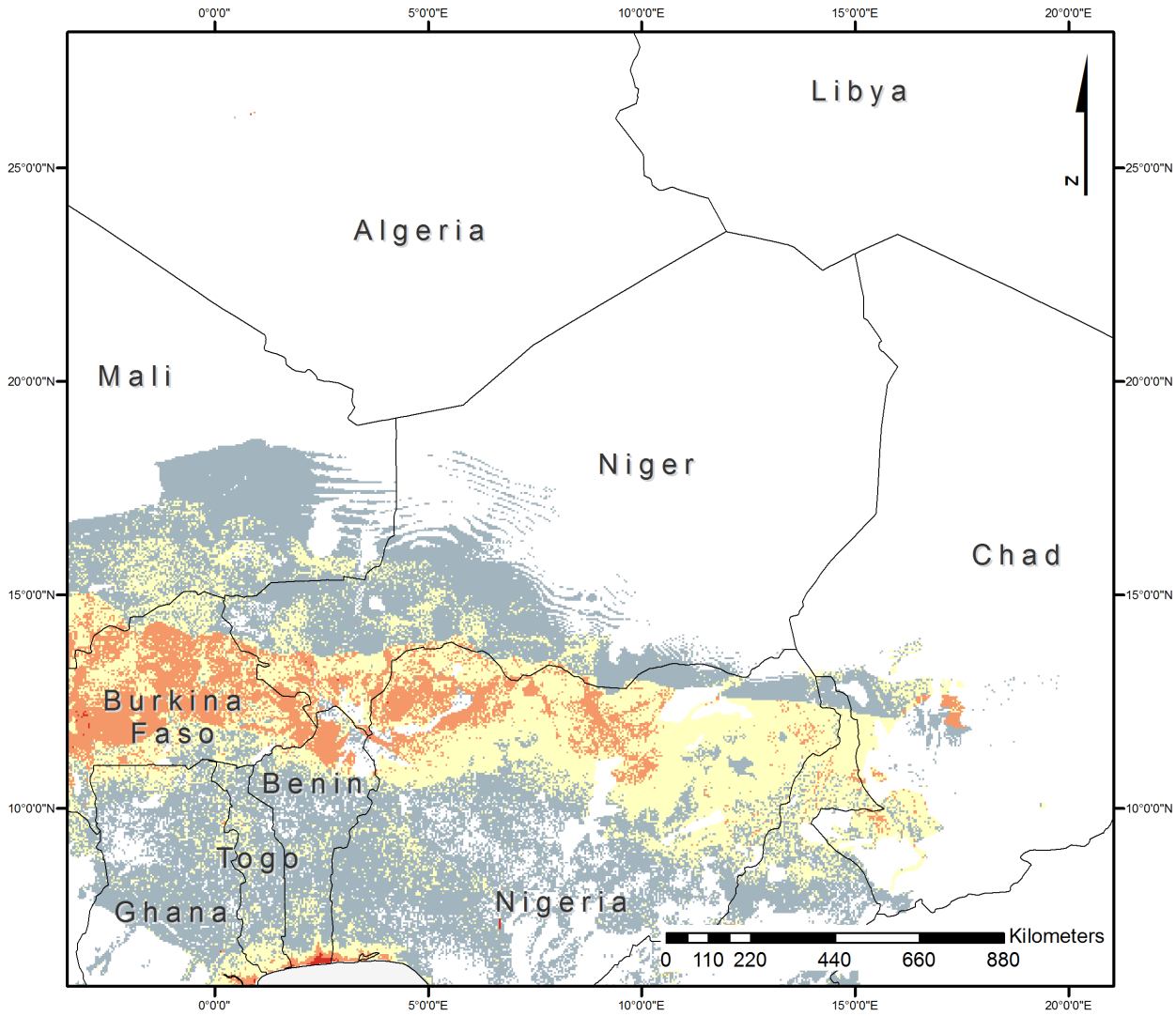
Anopheles (*Cel.*) *arabiensis* Patton, 1905

Ecological Niche Model

Anopheles arabiensis



0 - 0.2 Least suitable
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1 Most suitable

Habitat suitability model developed using maximum entropy (Maxent).
Access to model outputs can be found here:
http://vectormap.si.edu/Mosquito_Metadata.htm#vec43

WRBU VectorMap

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Anopheles (*Cel.*) *funestus* s.l.

Bionomics:

In most parts of its range, *An. funestus* s.s. breeds characteristically in bodies of clear water that are either large and more or less permanent, e.g. swamps (near edges if deep), weedy sides of streams, rivers, furrows or ditches, protected portions of lake shore, ponds, or water such as seepages, which are fed from underground permanent sources (Evans, 1938). It is one of the most anthropophilic mosquitoes known. *An. fumestus* s.s. is also strongly endophilic, resting indoors after blood meals. The great bulk of feeding takes place inside houses after 22:00h up to dawn (Gillies and deMeillon, 1968) with peak biting between 0300 to 0500.

Medical Importance:

An. funestus s.s. is a vector of *Plasmodium vivax, P. falciparum* and *Wuchereria bancrofti.* Pathogen screening has detected the following arboviruses, however, the vector capacity is unknown:

BOZOV, BUNV, BWAV, GERV, NDOV, NRIV, ONNV, ORUV, SFV, TANV, TATV

Labbo, R., Fouta, A., Jeanne, I., et al. (2004). *Anopheles funestus* in Sahel: new evidence from Niger. The Lancent, 363: 660.

Vector Base

WRBU Catalog

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Anopheles (*Cel.*) *gambiae s.l.*

Bionomics:

Anopheles gambiae s.s. is known as the most dangerous animal in the world. It is the dominant malaria vector in the Afrotropical region and is highly anthropophilic. *An. gambiae* s.s. has been found on sticky traps 40-240 m above the ground, giving the impression that it uses long-distance migration as a potential strategy of survival. These species occur in a great variety of types of water; the most striking are the shallow, open sun-lit pools. Females readily enter houses and bite man both indoors and outdoors starting at sunset and peaking just at dawn (Gillies and de-Meillon, 1968).

Medical Importance:

Anopheles gambiae s.s. is the primary malaria vector in Africa (Gillies and deMeillon, 1968). Pathogen screening has detected the following arboviruses and parasites, however, the vector capacity is unknown:

AnCV, AnCPV, AgDNV, AngFV, AToV, BARV, BWAV, CVOV, ILEV, NRIV, ONNV, ORUV, TAHV, TATV, WSLV, ZIKV, P. falciparum, P. gallinaceum (chicken), P. malariae, P. ovale

Maia, M.F., Kapulu, M., Muthui, M., Wagah, M.G., Ferguson, H.M., Dowell, F.E., Baldini, F. and Cartwright, L.R. (2019). Detection of *Plasmodium falciparum* infected *Anopheles gambiae* using near-infrared spectroscopy. Malaria Journal, 18:85.

Czeher, C., Labbo, R., Arzika, I. & Duchemin, J.-B. (2008). Evidence of increasing Leu-Phe knockdown resistance mutation in *Anopheles gambiae* from Niger following a nationwide long-lasting insecticide-treated nets implementation. Malaria Journal, 7(189).

Vector Base

WRBU Catalog

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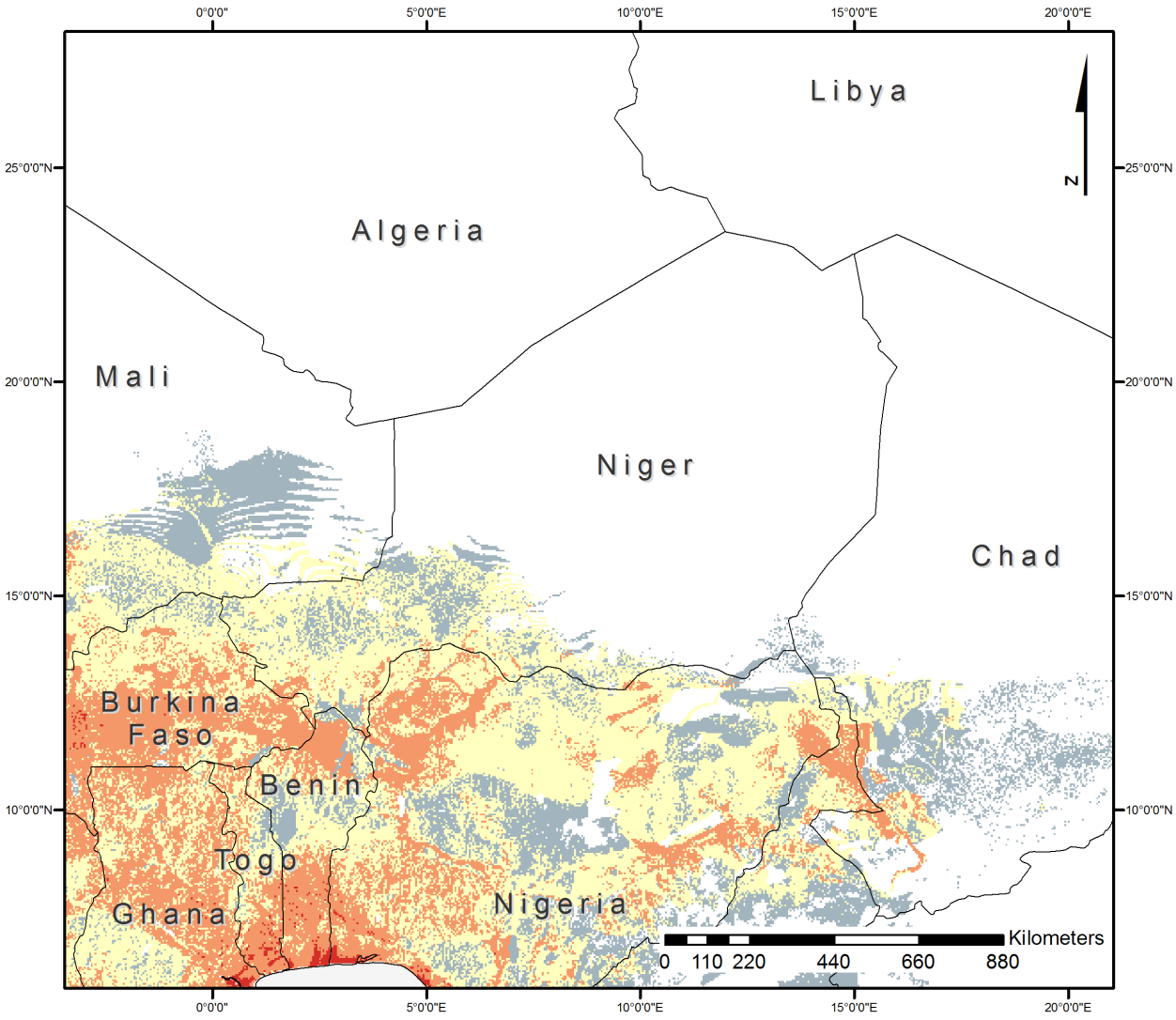
Anopheles (*Cel.*) *gambiae* s.l.

Ecological Niche Model

Anopheles gambiae s.l.



0 - 0.2 Least suitable
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1 Most suitable

Habitat suitability model developed using maximum entropy (Maxent).
Access to model outputs can be found here:
http://vectormap.si.edu/Mosquito_Metadata.htm#vec43

WRBU VectorMap

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Anopheles (*Cel.*) *moucheti* Evans 1925

Bionomics:

An. moucheti inhabits forest-edge environments, and its larvae are found along the borders of slow moving streams and large rivers or in pools or ponds with turbid water. It is a highly anthropophilic and endophilic species readily entering houses to feed (Gilles and deMeillon, 1968). *An. moucheti* bites throughout the night with peak biting between midnight and dawn.

Medical Importance:

An important vector of malaria where it occurs in any abundance (Gillies and deMeillon, 1968).

WRBU Catalog

Anopheles (*Cel.*) *nili* s.l.

Bionomics:

Anopheles nili s.s. is principally a stream breeder with larvae being found in vegetation or in dense shade along the edges of streams and large rivers. Symes (1931a) found that out of 163 collections of larvae of this species in Kenya, 139 were taken from streams. It is known to be an anthropophilic species biting man readily indoors and outdoors and frequently resting indoors by day (Gillies and deMeillon, 1968:85). Other members of this complex are known to be forest feeders who are primarily zoophilic but will opportunistically feed on man.

Medical Importance:

An important vector of malaria in many parts of West Africa. Wherever man-biting occurs infected specimens are found (Gillies and deMeillon, 1968:85).

Vector Base
WRBU Catalog

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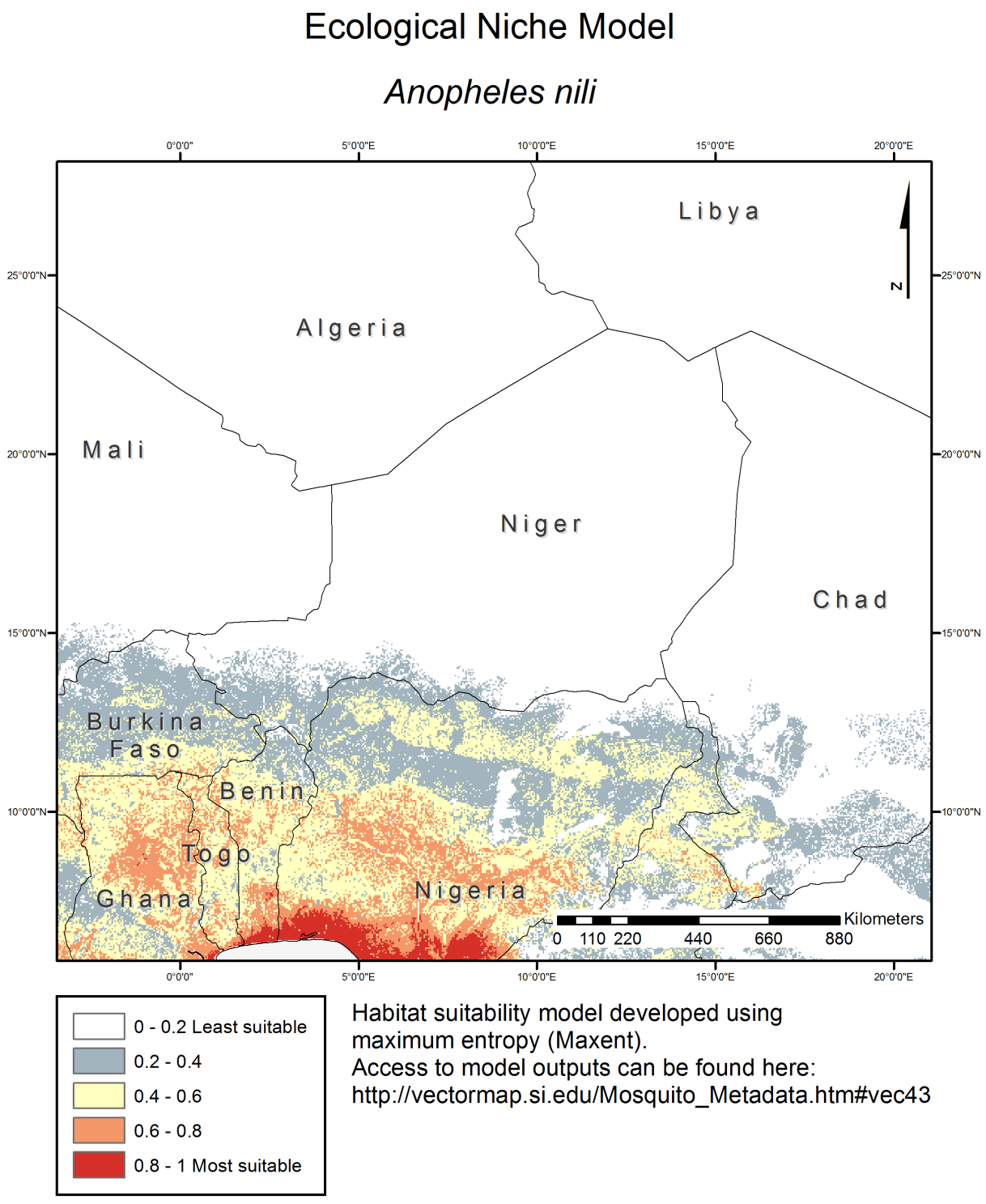
Anopheles (*Cel.*) *nili* s.l.



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Anopheles (*Cel.*) *pharoensis* s.l.

Bionomics:

Primarily a species of large vegetated swamps, but is also found along lake shores and among floating plants, such as *Pistia* and *Potamogeton*. It's also found in reservoirs rice fields, streams, ditches, and overgrown wells. They feed from dusk to dawn with a peak at about 01:00 and will enter homes to feed (Gillies and deMeillon, 1968). *An. pharoensis* s.s. is an opportunistic feeder.

Anopheles pharoensis, BOLD (License Holder: Yvonne U Ajamma)

Medical Importance:

A known vector of malaria in Egypt. In tropical Africa, at best it is a feeble vector of malaria (Gillies and deMeillon, 1968). Pathogen screening has detected the following arboviruses and parasites, however, the vector capacity is unknown:

BGIV, BIRV, RVFV, SINV, *Brugia* spp., *P. falciparum, P. vivax*

Hasaballah, A.I. (2018). The Biological Role of *Cymbopogon proximus* Leaf Extracts against the Malaria Vector, *Anopheles pharoensis*. Egyptian Academic Journal of Biological Sciences, 11(6): 63-76.

WRBU Catalog

Anopheles (*Cel.*) *multicolor* Cambouliu, 1902

Bionomics: *Anopheles multicolor* larvae tend to be found in small pools, stagnant or flowing drainage pools, and in other shallow unused wells both fresh and highly saline in nature—although they prefer brackish water. Adults are capable of flying nearly 13 km with desert winds (Russel, 1943), and females have been found 13 km away from ideal breeding habitats. *An. multicolor* will readily enter homes to feed on humans (Gillies & de Meillon, 1968). This species is generally exophilic outside of Egypt.

Medical Importance: *An. multicolor* is considered a secondary malaria vector (Gillies & deMeillon, 1968). Pathogen screening has detected RVFV, however, the vector capacity is unknown.

WRBU Catalog

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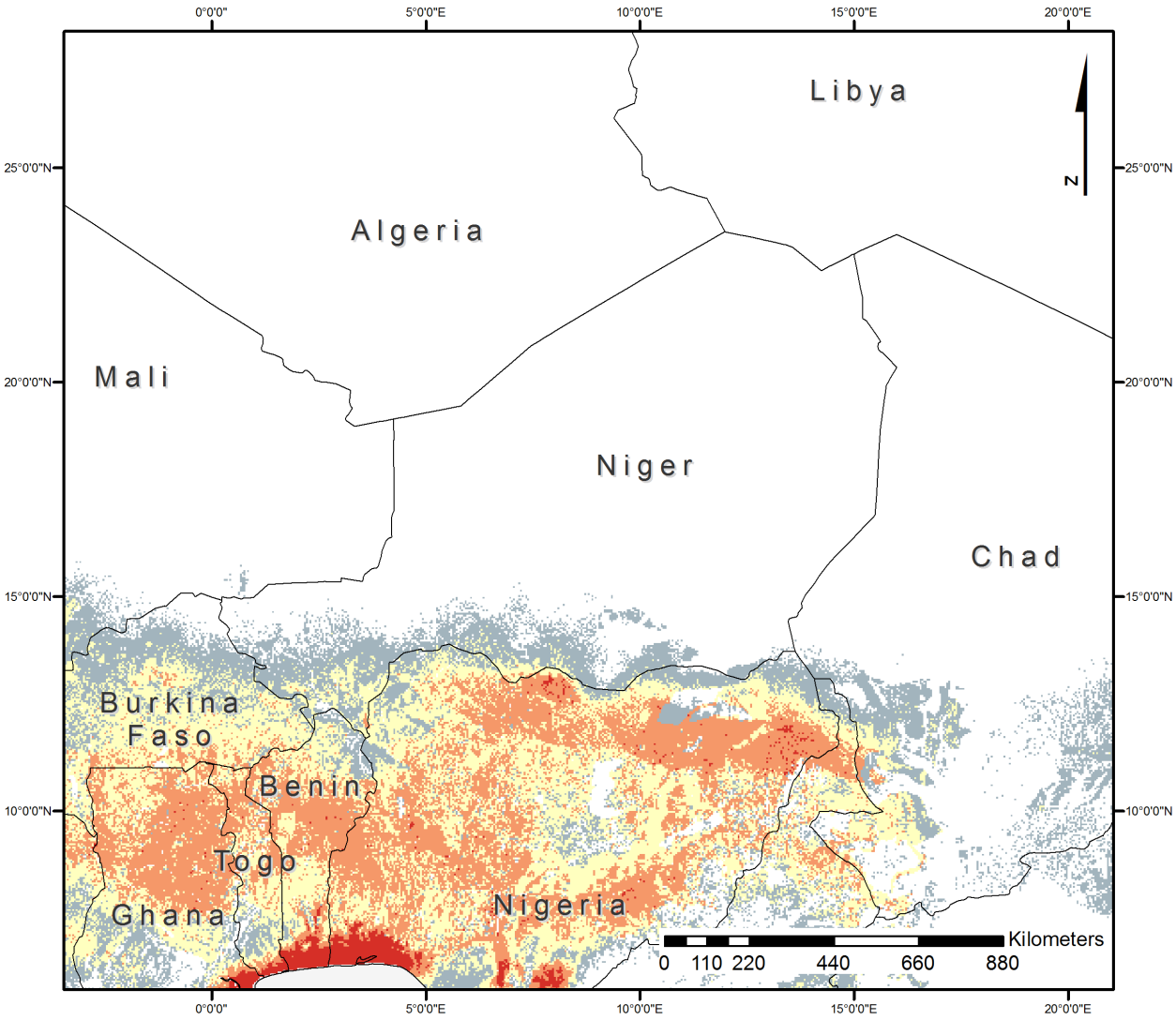
Anopheles (*Cel.*) *pharoensis* s.l.

Ecological Niche Model

Anopheles pharoensis



0 - 0.2 Least suitable
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1 Most suitable

Habitat suitability model developed using maximum entropy (Maxent).
Access to model outputs can be found here:
http://vectormap.si.edu/Mosquito_Metadata.htm#vec43

WRBU VectorMap

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Anopheles spp.

I. Vector Surveillance and Suppression: Light traps are used to collect night-biting mosquitoes, but not all *Anopheles* spp. are attracted to light. The addition of the attractant carbon dioxide to light traps increases the number of species collected. Traps using animals, or even humans, as bait are useful for determining feeding preferences of mosquitoes collected (use of humans as bait must be conducted under approved human use protocols). Adults are often collected from indoor and outdoor resting sites using a mechanical aspirator and flashlight. Systematic larval sampling with a long-handled white dipper provides information on species composition and population dynamics, which is used when planning control measures. Malaria suppression includes elimination of gametocytes from the blood stream of the human reservoir population, reduction of larval and adult Anopheles mosquito populations, use of personal protective measures such as skin repellents, permethrin impregnated uniforms and bed nets to prevent mosquito bites, and chemoprophylaxis to prevent infection. Application of residual insecticides to the interior walls of buildings and sleeping quarters is an effective method of interrupting malaria transmission when local vectors feed and rest indoors. Nightly dispersal of ultra low volume (ULV) aerosols can reduce exophilic mosquito populations. Larvicides and biological control with predaceous fish can control larvae at their aquatic developmental sites before adults emerge and disperse. For more information about Insecticides used for mosquito control consult the AFPMB Technical Guide No. 48, Contingency Pest Management and Vector Surveillance (CAC required). Chemical control may be difficult to achieve in some areas. After decades of malaria control, many vector populations are now resistant to insecticides. Sanitary improvements, such as filling and draining areas of impounded water to eliminate breeding habitats, should be used to the extent possible. The use of bed nets impregnated with a synthetic pyrethroid, preferably permethrin, is an extremely effective method of protecting sleeping individuals from mosquito bites. Buildings and sleeping quarters should be screened to prevent entry of mosquitoes and other blood-sucking insects. The interior walls of tents and bunkers can be treated with permethrin to control resting vectors.

II. Reported Insecticide Resistance:

Ndiath, M.O., Cailleau, A., Orlandi-Pradines, E., et al. (2015). Emerging knock-down resistance in *Anopheles arabiensis* populations of Dakar, Senegal: first evidence of a high prevalence of *kdr-e* mutation in West African urban area. Malaria Journal, 14:364.

Hancock, P.A., Wiebe, A., Gleave, K.A., et al. (2018). Associated patterns of insecticide resistance in field populations of malaria vectors across Africa. PNAS, 115(23): 5938-5943.

Namountougou, M., Soma, D.D., Kientega, M., et al. (2019). Insecticide resistance mechanisms in *Anopheles gambiae* complex populations from Burkina Faso, West Africa. Acta Tropica, 197:105054.

III. Vector Identification:

Illustrated Key to the Female Anopheles of Southwestern Asia and Egypt (Diptera: Culicidae)

LUCID Pictorial Key to the Medically Important Mosquitoes of AFRICOM

Gillies, M.T. and Coetzee, M. (1987). A supplement to the Anophelinae of Africa South of the Sahara (Afrotropical Region). The South African Institute for Medical Research. No. 55:1-143

Russel, P.F., Rozeboom, L.E. & Stone, A. (1943). Keys to the Anopheline Mosquitoes of the World. The American Entomological Society, Lancaster Press, Lancaster, Pennsylvania.

IV. Additional Resources:

Gay-Andrieu, F., Adehossi, E., Lacroix, Veronique, et al. (2005). Epidemiological, clinical and biological features of malaria among children in Niamey, Niger. Malaria Journal, 4:10.

Doudou, M.H., Mahamadou, A., Ouba, I., et al. (2012). A refined estimate of the malaria burden in Niger. Malaria Journal, 11(89).

Oxborough, R.M., Seyoum, A., Yihdego, Y., et al. (2019). Susceptibility testing of *Anopheles* malaria vectors with the neonicotinoid insecticide clothianidin; results from 16 African countries, in preparation for indoor residual spraying with new insecticide formulations. Malaria Journal, 18(24).

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Culex (*Cux.*) *quinquefasciatus* Say, 1823

Bionomics:

Immatures of *Cx. quinquefasciatus* have been found in domestic and peri-domestic habitats with clean or polluted water. Typical larval localities are sewers, ditches, agricultural seepage pits, etc. This species is an opportunistic feeder but primarily anthropophilic. *Cx. quinquefasciatus* feeds indoors and outdoors at night and will rest both indoors and outdoors as well. Larvae can be found in bodies of water containing a high degree of organic pollution and close to human habitation. Females readily enter houses at night and bite man in preference to other mammals (Sirivanakarn 1976).

Medical Importance:

This species is a vector of avian malaria, a primary vector of *Wuchereria bancrofti*, Western equine encephalomyelitis, St. Louis encephalitis and West Nile. Pathogen screening has detected the following arboviruses and one parasite, however, the vector capacity is unknown:

AMTV, APEUV, APV, BEFV, BUNV, CHIKV, CHPV, CWV, EEEV, EHDV, GFV, INGV, JEV, KOTV, KOWV, KRIV, KUNV, MAGV, MVEV, NEPV, NTAV, ORIV OROV, PARAV, ROCV, RVFV, SFSV, SFV, STRV, TURV, USUV, VEEV, VSAV, VSIV, VSNJV, WANV, ZEGV, *P. relictum*

Bhattacharya, S. & Basu, P. (2016). The Southern House Mosquito, *Culex quinquefasciatus*: profile of a smart vector. Journal of Entomology and Zoology Studies, 4(2): 73-81.

WRBU Catalog

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Culex (*Cux*.) *univittatus* Theobald, 1901

Bionomics:

The distribution of *Culex univittatus* has historically been misidentified as a number of similar species making some of its bionomic information and distribution doubtful. Larvae of *Cx. univittatus* are found in ground pools, marshy pools, barrow pits, stagnant drains and streams, canals and shallow wells. Females feed primarily on birds and mammals but will opportunistically feed on humans. Feeding times range from sunset to sunrise with a peak around midnight.

Medical Importance:

Cx. univittatus is known to vector West Nile, Sindbis, and *Wuchereria bancrofti*. Pathogen screening has detected the following arboviruses, however, the vector capacity is unknown:

BAGV, OLIV, SPOV, USUV, WEEV, WSLV

WRBU Catalog

Biting Times:	18:00-06:00
Host Preference:	Anthropophilic and Zoophilic
Feeding Behavior:	Exophagic and Endophagic
Resting Behavior:	Exophilic and Endophillic

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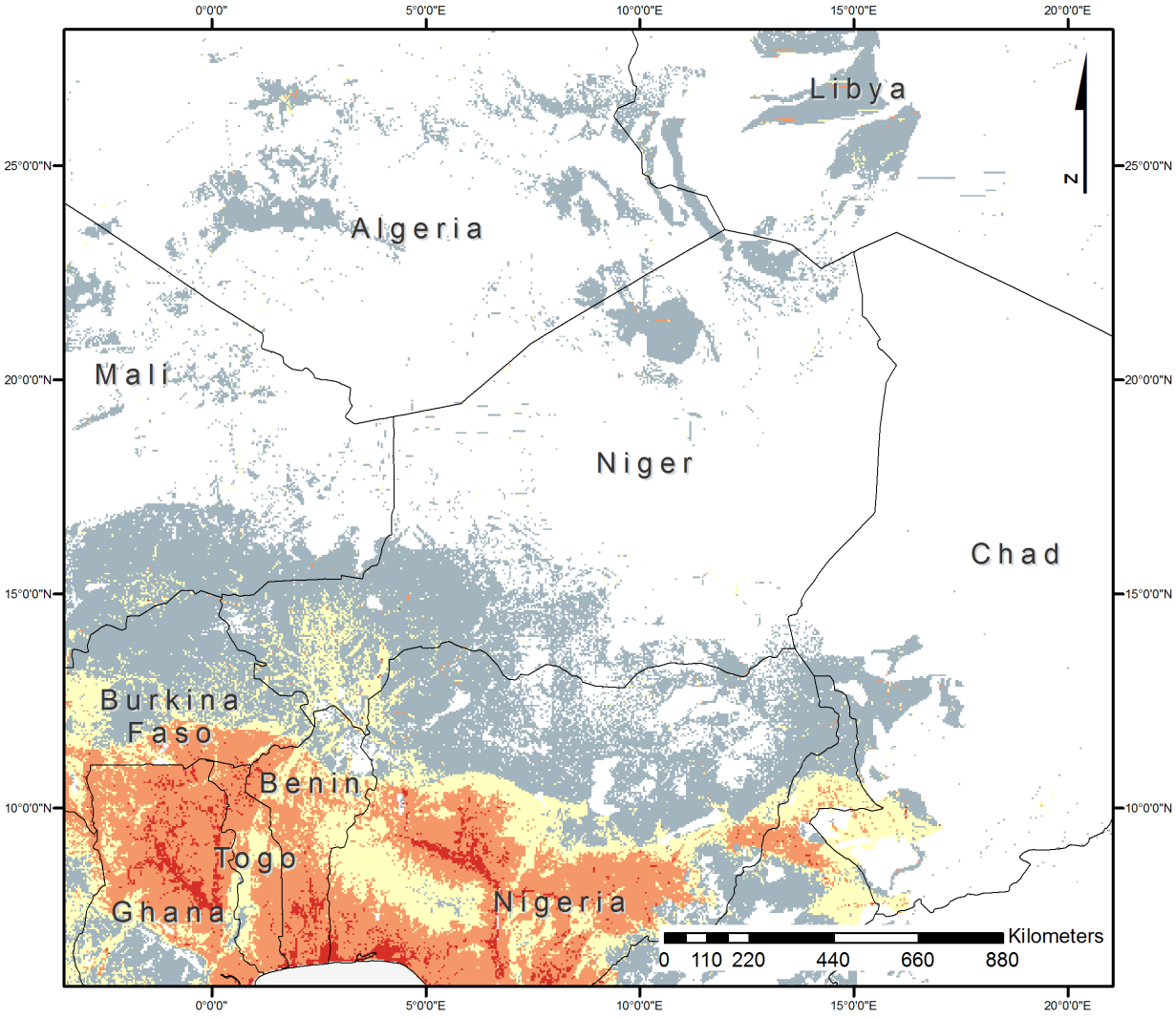
Culex (*Cux.*) *univittatus* Theobald, 1901

Ecological Niche Model

Culex univittatus



Habitat suitability model developed using maximum entropy (Maxent).
Access to model outputs can be found here:
http://vectormap.si.edu/Mosquito_Metadata.htm#vec43

WRBU VectorMap

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Culex spp.

I. Vector Surveillance and Suppression: Reduction of mosquito populations by ultra-low volume (ULV) spraying may be useful as a means of disease control. The most feasible long-term control strategies involve reducing vector breeding by environmental management techniques. Personal protective measures to prevent mosquito bites are the most practical means of avoiding infection with WNV and Sindbis virus. Consult AFPMB Technical Guide No. 13: Dispersal of Ultra Low Volume (ULV) Insecticides by Cold Aerosol and Thermal Fog Ground Application Equipment; AFPMB Technical Guide No. 24: Contingency Pest Management Guide, and AFPMB Technical Guide No. 40: Methods for Trapping and Sampling Small Mammals for Virologic Testing.

II. Reported Insecticide Resistance:

Norris, L.C. & Norris, D.E. 2011. Insecticide resistance in *Culex quinquefasciatus* mosquitoes after the introduction of insecticide-treated bed nets in Macha, Zambia. Journal of Vector Ecology. 36(2): 411-420.

Magnin, M., Marboutin, E., & Pasteur, N. (1988). Insecticide Resistance in *Culex quinquefasciatus* (Diptera: Culicidae) in West Africa. Journal of Medical Entomology, 25(2): 99-104.

III. Vector Identification:

Harbach, R.E. 1985. Pictorial keys to the genera of mosquitoes, subgenera of Culex and the species of Culex (Culex) occurring in southwest Asia and Egypt, with a note on the subgeneric placement of Culex deserticola (Diptera: Culicidae). Mosquito Systematics. 17: 83-107.

LUCID Pictorial Key to the Medically Important Mosquitoes of West Africa, AFRICOM (WRBU)

IV. Additional Resources:

CABI, 2017. *Culex quinquefasciatus* (southern house mosquito). In: Invasive Species Compendium. Wallingford, UK: CAB International. https://www.cabi.org/isc/datasheet/86848

Koudou, B.G., de Souza, D.K., Biritwum, N.-K., et al. (2018). Elimination of lymphatic filariasis in west African urban areas: Is implementation of mass drug administration necessary? The Lancet Infectious Diseases, 18(6): PE214-E220. doi: http://dx.doi.org/10.1016/ S1473-3099(18)30069-0

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Mansonia (*Mnd.*) *uniformis* (Theobald, 1901)

Bionomics:

Mansonia uniformis has a wide distribution, is highly exophagic and zoophilic (cattle) but will readily bite man and other mammals. Its peak feeding time is between 19:00-20:00 after sunset. Immatures are found in open swamps unshaded by trees and have been found in rice fields as well. Larvae use specially modified siphons to pierce stems and roots of aquatic vegetation to obtain air. (Wharton, 1962).

Medical Importance:

Vector of *Wuchereria malayi* (Wharton, 1962), Rift Valley fever (Zeller, 1997), and yellow fever. Pathogen screening has detected the following arboviruses and parasites, however, the vector capacity is unknown:

BUNV, JBEV, KAVV, MALV, NDUV, ONNV, PGAV, PUCV, RRV, SPOV, YATAV, *Brugia patei, B. malayi, B. pahangi, Dirofilaria repens, Plasmodium cynomolgi bastianelii*

Ughasi, J., Bekard, H.E., Coulibaly, M., Adabie-Gomez, D., Gyapong, J., Appawu, M., Wilson, M.D. and Boakye, D.B. (2012). *Mansonia africana* and *Mansonia uniformis* are Vectors in the transmission of *Wuchereria bancrofti* lymphatic filariasis in Ghana. Parasites & Vectors, 5:89.

WRBU Catalog

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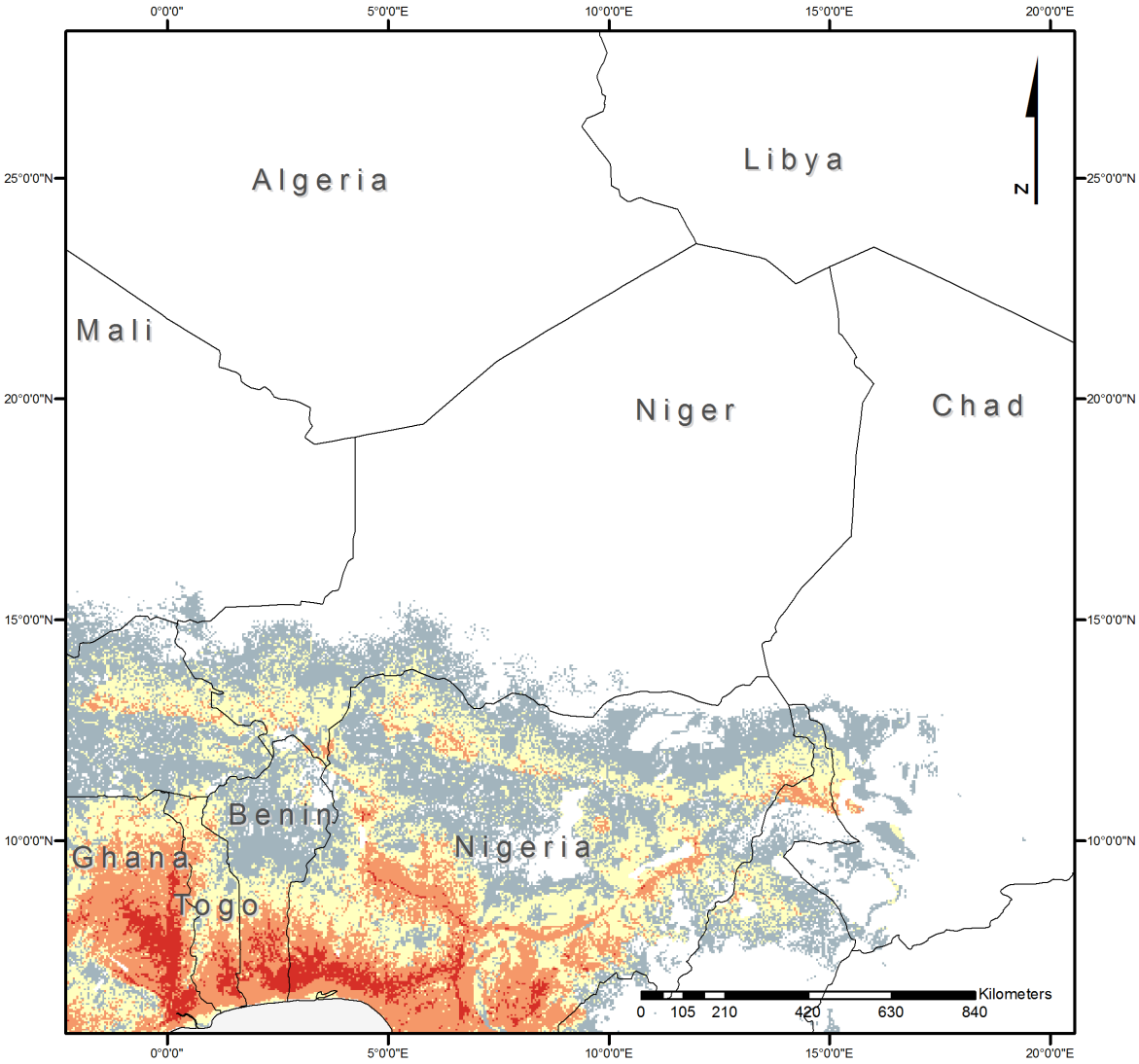
Mansonia (*Mnd.*) *uniformis* (Theobald, 1901)

Ecological Niche Model

Mansonia uniformis



0 - 0.2 Least suitable
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1.0 Most suitable

Habitat suitability model developed using maximum entropy (Maxent).
Access to model outputs can be found here:
http://vectormap.si.edu/Mosquito_Metadata.htm#vec43

WRBU VectorMap

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Sand Fly Vector Species Profiles

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Sand Flies of Niger

I. General Information:

Adult sand flies rest during the daytime in dark, humid, protected areas, such as rodent burrows, rock crevices and caves. The preparation of military bunkered ground positions in desert areas provides additional protected daytime resting sites for phlebotomine sand flies. In urban areas, sand fly adults often rest in dark, cool, humid corners of inhabited human and animal structures. Abandoned structures and their vegetative overgrowth often become attractive wild rodent habitats and foci of rural CL. Vegetation is important as a sugar source for both male and female sand flies, and sugar is required for females developing parasite infections. Eggs are developed after a blood meal and are deposited in dark, humid, protected areas. They develop into minute caterpillar-like larvae that feed on mold spores and organic debris. The larvae go through four instars and then pupate near larval feeding sites. Development from egg to adult is 30 to 45 days, depending on feeding conditions and environmental temperatures. Phlebotomine sand fly eggs, larvae and pupae have seldom been found in nature due to their minute and delicate nature, although exhaustive studies and searches have been made. The adult female has been observed to spread eggs around rather than ovipositing in single egg laying sites. The larvae are believed to be widely distributed in endemic environments but are probably below the ground surface in termite mounds, rodent burrows or other tunnels where temperature, humidity and mold growth provide ideal growing conditions. The dusk to dawn movement of adults is characterized by flight just above the ground surface to avoid wind. Adult sand flies generally do not travel great distances, and most flights are believed to be less than 100 meters. The females fly in a low hopping flight just above the ground in search of rodent hosts. Vector sand flies have short flight ranges. Their dusk to dawn flights coincide with the nomadic activity of peoples of the region, who often travel at night to avoid the extreme heat of daytime hours. Areas with some vegetation, and cliffs, rock outcroppings, or other geologic formations that allow for suitable hiding places and daytime resting sites are important habitats. Throughout arid and semi-arid habitats, the population of sand flies typically peaks near the rainy season's end and are the lowest at the end of the dry season. Exact information on reservoirs and vectors will require more extensive study in many countries of the region. Vast areas of these countries remain unsurveyed for vectors and disease. When searches are made, sand fly vectors are often found in areas where they were previously unknown.

II. Vector Surveillance and Suppression:

Sand flies may be collected by a variety of methods. Light traps used for mosquito collection should be modified with fine mesh screens because the small size of phlebotomine sand flies allows them to pass through normal mosquito netting. Sticky traps prepared with paper and vegetable or plant oil are useful and may be placed near rodent burrows, rock crevices, building debris, in and around buildings or constructed military earthworks, and in local vegetation where sand flies are likely to rest during daytime hours. The sticky paper trap is also useful where light traps are either unavailable or their use is limited due to night security measures. Aspirator collections by trained personnel from sand fly resting sites are useful but labor intensive. Identification requires a microscope and some training; however, with some experience, sorting and identification by color and size is quite accurate using minimal magnification. For proper species identification, laboratory microscopes having 100X magnification are required or molecular barcoding. Sand flies are susceptible to most pesticides, and residual insecticide spraying of grounds/structures (inside and outside walls) of encampment areas, coupled with barrier spraying of 200 m of territory surrounding encampment sites, is effective. When the use of organophosphates or other insecticides is impractical due to the combat situation or other operational requirements, personal protective measures (proper wearing of permethrin-treated uniforms and skin repellents) will provide nearly complete protection. Normal mosquito bed nets and screening are ineffective because of the ability of sand flies to crawl through the mesh. Commanders must inform troops of the risks of infection and monitor the proper wearing of uniforms and use of skin repellents. Since small desert rodents are often the normal hosts of sand flies, selection of encampment sites without vegetation or rock outcroppings that enhance rodent harborage is important. Cleanup and removal of garbage and debris that encourage rodent harborage are necessary for longer periods of occupation. Where combat situations outweigh selection and cleanup, residual insecticide spraying will greatly reduce sand fly prevalence. Again, proper wearing of treated uniforms and use of skin repellents will suffice where other control measures cannot be used to reduce sand fly incidence. Pets must be strictly prohibited because any small desert rodent and/or local dog may be infected with cutaneous or visceral leishmaniasis and other infectious diseases. For more information on control strategies for sand flies consult the AFPMB Technical Guide No. 49: Sand Flies (Diptera: Psychodidae: Phlebotominae): Significance, Surveillance, and Control in Contingency Operations.

III. Vector Identification:

LUCID Pictorial Key to the Medically Important Sand Flies of AFRICOM (WRBU)

Mukhopadhyay, J., Ghosh, K. & Braig, H.R. (2000). Identification of cutaneous Leishmaniasis vectors, Phlebotomus papatasi and P. duboscqi using random amplified polymorphic DNA. Acta Tropica, 76: 277-283.

IV. Additional Resources:

ECDC Phlebotomines

Abonnenc, E. & Minter, D.M. (1965). Bilingual keys for the identification of the sandflies of the Ethiopian Region. ORSTOM, Paris.

Ghazanfar, M. & Malik, M.F. (2016). Sandfly and Leishmaniasis: A Review. Journal of Ecosystem & Ecography, 6:3.

Claborn, D.M. 2010. The biology and control of leishmaniasis vectors. Journal of Global Infectious Diseases. 2(2): 127-134.

Lewis, D.J. (1971). Phlebotomid Sandflies. The Bulletin of the World Health Organization, 44: 535-551.

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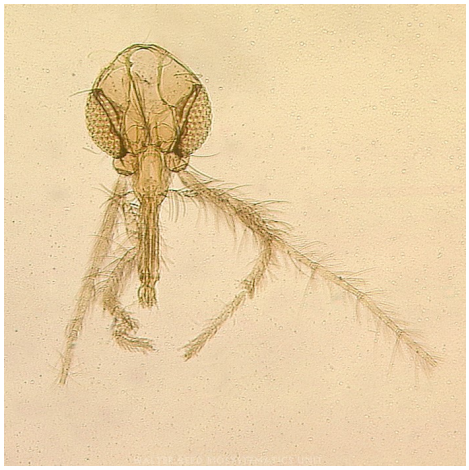
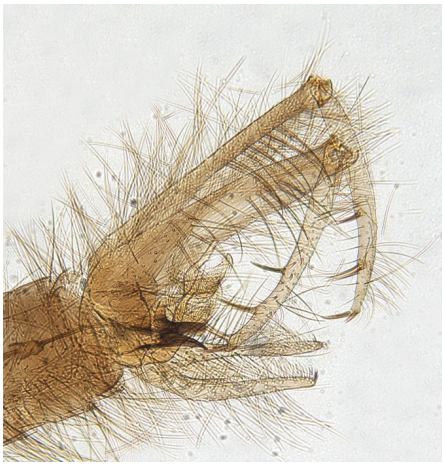
Phlebotomus (*Phb.*) *duboscqi* Neveu-Lemaire, 1906



Bionomics: The distribution of *Phlebotomus duboscqi* seems to be limited to the arid and semi-arid areas of savanna land in which it uses termite hills as its main location of breeding in West Africa (Asimeng, 1985). This species is exophagic and breeds year round. It will opportunistically feed on humans in areas of plentiful vegetation and animal burrows (Anjili, 2011).

Medical Importance: Proven vector of *L. major* in Senegal and Kenya and suspected vector throughout the Sahel region of Africa (Dedet *et al.*, 1979; Killick-Kendrick, 1990). [Seccombe & Ready 1993: 15]



Kimutai, A., Ngeiywa, M., Mulaa, M., Njagi, P.G.N., Ingonga, J., Nyamwamu, L.B., Ombati, C. and Ngumbi, P. (2017). Repellent effects of the essential oils of *Cymbopogon citratus* and *Tagetes minuta* on the sandfly, *Phlebotomus duboscqi*. BMC Research Notes, 10:98.

Anderson, J.M., Samake, S., Jaramillo-Gutierrez, G., et al. (2011). Seasonality and Prevalence of *Leishmania major* Infection in *Phlebotomus duboscqi* Neveu-Lemaire from Two Neighboring Villages in Central Mali. PLoS Neglected Tropical Diseases, 5(5): e1139.

Kasili, S., Kutima, H., Mwandawiro, C., Ngumbi, P.M. and Anjili, C.O. (2009). Comparative attractiveness of C02-baited CDC light traps and animal baits to *Phlebotomus duboscqi* sandflies. Journal of Vector Borne Diseases, 46: 191-196.

Asimeng, E.J. (1985). The distribution of Phlebotomus duboscqi with reference to the known foci of cutaneous leishmaniasis in Northern Nigeria. International Journal of Tropical Insect Science, 5(1): 27-31.

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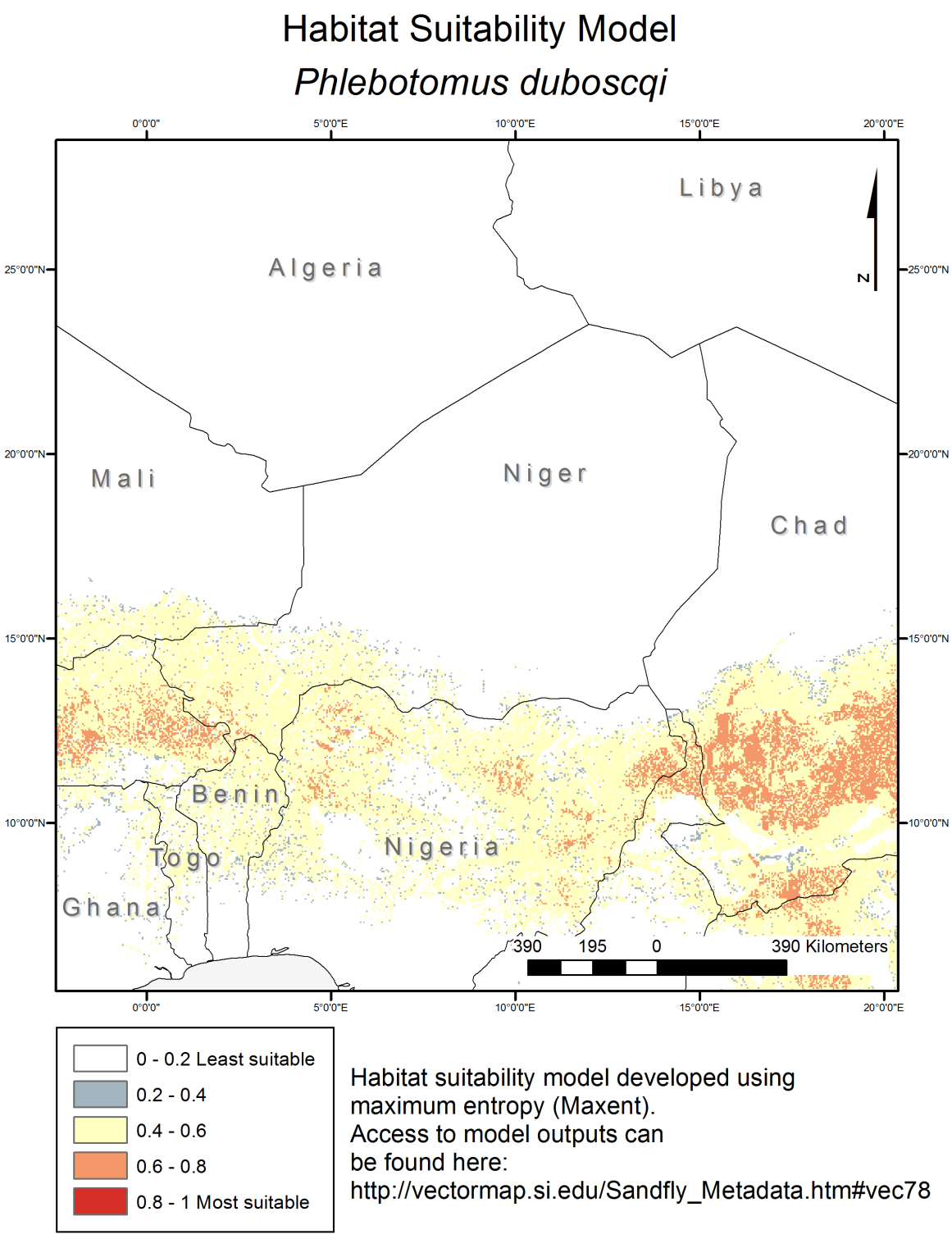
Phlebotomus (*Phb.*) *duboscqi* Neveu-Lemaire, 1906



Habitat suitability model developed using maximum entropy (Maxent).
Access to model outputs can be found here:
http://vectormap.si.edu/Sandfly_Metadata.htm#vec78

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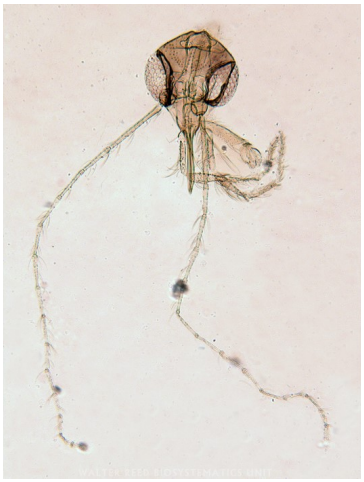
Phlebotomus (*Pab.*) *sergenti* Parrot, 1917

Bionomics: *Ph. sergenti* is capable of being an opportunistic feeder, however, it is noted to be highly anthropophilic. Females are exophilic and exophagic (Moncaz *et al*., 2012) this species extends further north than *P. papatasi* (Adler & Theodor, 1957; Lewis & Ward, 1987).

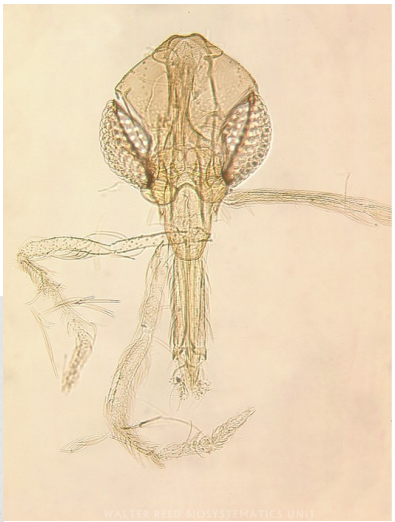
Medical Importance: *Ph. sergenti* is the primary vector of *Leishmania tropica* in many regions of its distribution (Maroli *et al*., 2009; Orshan *et al*., 2010). This species is also susceptible to *L. major* (Seccombe & Ready, 1993).



WRBU Catalog

Phlebotomus (*Phb.*) *papatasi* Scopoli, 1786

Bionomics: *Ph. papatasi* is typically opportunistic in feeding habits, but is capable of being highly anthropophilic when possible. Females have been seen to enter houses to bite humans very readily. (AFPMB, No. 49). The type habitat of this species is broadleaf forest and is also found to be abundant in small rodent burrows.



Medical Importance: *Ph. papatasi* is a vector of *L. major* to man and gerbils in U.S.S.R., Saudi Arabia, southern Morocco and central Tunisia (Killick-Kendrick, 1990; Killlck-Kendrick, 1985; Lane & Fritz, 1986; Perfil'ev, 1966); suspected vector of *L. arablea* in Saudi Arabia (Killick-Kendrick, 1990). Naples and Sicilian viruses were found infecting man only where this sandfly occurs (Tesh, 1988; Tesh *et al.*, 1976)

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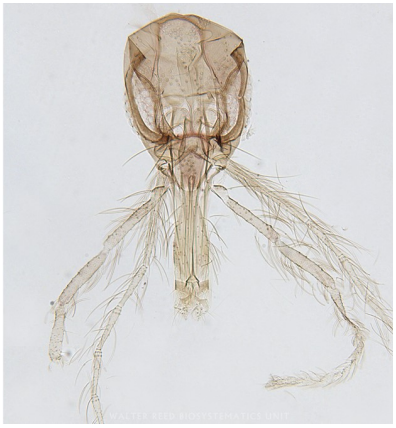
Phlebotomus (*Lar.*) *orientalis* (Parrot, 1936)

Bionomics: *Ph. orientalis* is distributed throughout the Sahel region in Niger. The type habitat of *Ph. orientalis* is prairie/mountain vegetation.

Medical Importance: *Ph. orientalis* is a known vector of *L. donovani* (or *L. archibaldi*) and main human-biter in the Acacia-Balonites forests of Sudan (Hoogstraal & Heyneman, 1969; Killick-Kendrick, 1990) [Seccombe & Ready 1993: 11].



Gebresilassie, A., Yared, S., Aklilu, E., et al. (2015). The influence of moonlight and lunar periodicity on the efficacy of CDC light trap in sampling Phlebotomus (Larroussius) orientalis Parrot, 1936 and other Phlebotomus sandflies (Diptera: Psychodidae) in Ethiopia. Parasites & Vectors, 8(106).

Elnaiem, D.E.A. (2011). Ecology and control of the sand fly vectors of *Leishmania donovani* in East Africa, with special emphasis on *Phlebotomus orientalis*. Journal of Vector Ecology, 36 (Supplement 1): S23-S31.

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Tick Vector Species Profiles
Ixodidae (hard) ticks

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Ixodidae (hard) ticks

Bionomics (General): Vector ticks, and hence their diseases, tend to be more urban than rural in distribution because they are associated with hosts found in urban areas. The brown dog tick, in particular, tends to be more concentrated in urban areas, where its canine hosts are abundant. After feeding, females drop from the host and oviposit.

Medical Importance: *Hyalomma rufipes* & *H. truncatum* are considered the primary tick vectors of CCHF, however, multiple other species, such as *Amblyomma variegatum* and *Rhipicephalus pulchellus* are capable of transmission. Their importance depends heavily on host preference. *Hyalomma dromedarii* and *H. impeltatum* are primarily enzootic vectors. *Rhipicephalus sanguineus*, the brown dog tick, is a suspected zoonotic vector of CCHF and will feed on humans whenever close associations occur. Enzootic infection in dogs, rodents and other animals is usually subclinical. Transmission to humans is by bite of infected ticks. Contamination of breaks in the skin or mucous membranes with crushed tissues or feces of infected ticks can also lead to infection. Several species of Ixodid ticks transmit *C. burnetii* and other viruses and parasites to animals but are not an important source of human infection.

Vector Identification:

Abdullah, H.H. 2016. Morphological and molecular identification of the brown dog tick *Rhipicephalus sanguineus* and the camel tick *Hyalomma dromedarii* (Acari: Ixodidae) vectors of Rickettsioses in Egypt. Veterinary World. (10): 1087-1112.

Walker, A.R., Bouattour, A., Camicas, J.-L., Estrada-Pena, A., Horak, I.G., Latif, A.A., Pegram, R.G. & Preston, P.M. (2014) Ticks of Domestic Animals in Africa: a guide to identification of species. Bioscience Reports, Edinburgh, Scotland, UK.

Additional Resources:

Irvin, A.D., McDermott, J.J. & Perry, B.D. (eds). Epidemiology of Ticks and Tick-borne Diseases in Eastern , Central and Southern Africa. Proceeds of a Workshop Held in Harare, 12-13 March 1996. ILRI (International Livestock Research Institute), Nairobi, Kenya.

Trape, J.-F., Duplantier, J.M., Bouganali, H., et al. (1991). Tick-borne borreliosis in West Africa. The Lancet, 337(8739): 473-475.

Zeller, H.G., Cornet, J.-P. & Camicas, J.-L. (1994). Experimental transmission of Crimean-Congo Hemorrhagic Fever Virus by West African Wild Groun-Feeding Birds to *Hyalomma marginatum rufipes* Ticks. The American Journal of Tropical Medicine and Hygiene, 50(6), 676-681.

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Ixodidae (hard) ticks

Amblyomma variegatum, Photo credit AFPMB

Amblyomma variegatum Fabricius 1794
AFPMB, 2017

Bionomics	This species is a three-host tick.
Medical Importance	Crimean-Congo Hemorrhagic Fever
Host Preference	Sheep and cattle, and occasionally humans.

Rhipicephalus sanguineous, Photo credit J. Stoffer WRBU

Rhipicephalus sanguineous (Latreille, 1806)
WRBU, 2016

Bionomics	This species is a three-host tick that is prevalent in urban areas because of its close association with dogs.
Medical Importance	Crimean-Congo Hemorrhagic Fever, Boutonneuse Fever
Host Preference	Dogs but also feeds on camels, gerbils and, occasionally, humans.
Oviposition	*Rhipicephalus* sp. ticks, lay hundreds of eggs, generally in the dens of host animals, especially canines.
Questing Behavior	Adult *Rhipicephalus* sp. are passive in their host-questing activity (rarely moving more than 2 m)

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Ixodidae (hard) ticks

Hyalomma truncatum Photo credit AFPMB

Hyalomma truncatum Koch, 1844
AFPMB, 2017

Bionomics	This species is usually a two-host tick that is found in floodplains in semi-deserts and steppes, or vegetated hillsides and mountainsides are preferred habitats.
Medical Importance	Crimean-Congo Hemorrhagic Fever
Host Preference	Cattle, camels and sheep, immature stages tend to parasitize ground-feeding birds.
Oviposition	*Hyalomma* sp. ticks, the number of eggs laid is variable, ranging from hundreds in rodent burrows to thousands on open ground or vegetation. Eggs usually hatch within 30 days.

Hyalomma dromedarii Photo credit AFPMB

Hyalomma dromedarii Koch, 1844
AFPMB, 2017

Bionomics	This species may be either a two- or three -host tick.
Medical Importance	Crimean-Congo Hemorrhagic Fever
Host Preference	Camels, cattle, goats, dogs, small mammals, lizards and occasionally humans
Oviposition	*Hyalomma* sp. ticks, the number of eggs laid is variable, ranging from hundreds in rodent burrows to thousands on open ground or vegetation. Eggs usually hatch within 30 days.

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Ixodidae (hard) ticks

Hyalomma impeltatum Schulze & Schlottke, 1930	Crimean-Congo Hemorrhagic Fever (CCHF)	This species is usually a two-host tick that lives in scattered foci of semi-desert, savanna, and steppe biotopes.	Camels, cattle, rodents, hares, ground birds and other large domestic animals	*Hyalomma* sp. ticks, the number of eggs laid is variable, ranging from hundreds in rodent burrows to thousands on open ground or vegetation. Eggs usually hatch within 30 days.
Hyalomma rufipes Koch, 1844	Crimean-Congo Hemorrhagic Fever (CCHF), Tick Typhus	This species is a two-host tick.	Cattle, sheep, goats, horses and wild unglates.	*Hyalomma* sp. ticks, the number of eggs laid is variable, ranging from hundreds in rodent burrows to thousands on open ground or vegetation. Eggs usually hatch within 30 days.

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Other Vector Species Profiles

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Xenopsylla cheopis (Rothschild, 1903)

Bionomics: *X. cheopis* occurs primarily where commensal rodents are found, particularly *Rattus norvegicus*. Hosts, as well as the primary vector, are more widely distributed in urban areas. *X. cheopis* may occur sporadically in villages, when rats are present, or in highlands, associated with gerbils. The distribution of the Oriental rat flea is determined by the distribution of its hosts, primarily *R. rattus*, *R. norvegicus*, *Mus musculus*, *Meriones* spp. and *Psammomys* spp. (gerbils). Adult fleas feed exclusively on blood and utilize blood protein for egg production. After feeding on a rodent, the female Oriental rat flea lays several (2 to 15) eggs. Several hundred eggs may be laid during the entire life span. Oviposition most often occurs on the hairs of the host, although the eggs drop off and hatch in the nest or its environment. In locally humid environments, such as rodent burrows, eggs may hatch in as little as 2 days. Larvae live in the nest and feed on dried blood, dander, and a variety of organic material. They grow rapidly when temperature exceeds 25°C and the relative humidity is greater than 70%. The larval stages can be completed in as little as 14 days (at 30 to 32°C), or as long as 200 days when temperatures drop below 15°C or when nutrition is inadequate. Mature larvae pupate in cocoons, loosely attached to nesting material. Adult emergence from pupae may occur in as little as 7 days or as long as a year and is stimulated by carbon dioxide or host activity near the cocoon. Adult fleas normally await the approach of a host rather than actively search for one. They feed on humans when people and rodents live close together, but humans are not a preferred host. However, if rat populations decline suddenly due to disease or rat control programs, fleas readily switch to feeding on humans. The life span of adult *X. cheopis* is relatively short compared to that of other fleas species.

Medical Importance:

X. cheopis is considered a primary vector of Plague and Murine Typhus.

Xenopsylla cheopis Female, Photo credit J. Stoffer WRBU

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Xenopsylla cheopis (Rothschild, 1903)

I. Vector Surveillance and Suppression:

The methods of flea surveillance depend upon the species of flea, the host, the ecological situation, and the objective of the investigation. Fleas can be collected from hosts or their habitat. The relationship of host density to flea density should be considered in assessing flea populations. It has been common practice for years to use a flea index (average number of fleas per host), especially in studies of rodent fleas. For *X. cheopis*, a flea index > 1.0 flea per host is considered high. The flea index has many limitations, since only adults are considered and then only while they are on the host. Fleas are recovered by combing or brushing the host or by running a stream of carbon dioxide through the fur while holding the host over a white surface. Flea abundance in the environment can be determined by counting the number of fleas landing or crawling in one minute on the lower parts of the legs of the observer. The trouser legs should be tucked into the socks to prevent bites. Flea populations can also be estimated by placing a white cloth on the floor in buildings or on the ground in rodent habitat and counting the fleas that jump onto the cloth. Various flea traps have been devised. Some use light or carbon dioxide as an attractant. Use of a modified Tullgren apparatus, based of the Berlase funnel, sifting and flotation of rodent nesting materials and dust and debris from infested buildings are effective methods of collecting fleas from the environment. Serologies of wild carnivores are sensitive indicators of enzootic plague. Control of enzootic plague over large areas is not feasible. Control efforts should be limited to foci adjacent to urban areas, military encampments, or other areas frequented by military personnel. If possible, cantonment sites should not be located in wild rodent habitat. Fleas quickly leave the bodies of dead or dying rodents in search of new hosts. Consequently, flea control must always precede or coincide with rodent control operations. Application of insecticidal dusts to rodent burrows is effective in reducing flea populations, but it is very labor intensive. Baiting with formulations that rodents carry to their dens or with baits containing systemic insecticides that kill fleas when they feed, has been effective but may pose environmental risks. Urban plague control requires that rodent runs, harborages and burrows be dusted with an insecticide labeled for flea control and known to be effective against local fleas. Insecticide bait stations can also be used. Rat populations should be suppressed by well planned and intensive campaigns of poisoning and concurrent measures to reduce rat harborages and food sources. Buildings should be rat-proofed to the extent possible to prevent rats from gaining entry. Insecticides recommended for flea control are listed in AFPMB Technical Guide No. 24, Contingency Pest Management Guide. Military personnel, especially those involved in rodent control, should use the personal protective measures discussed in AFPMB Technical Guide No. 36: Personal Protective Techniques Against Insects and Other Arthropods of Military Significance. Active immunization with a vaccine of killed bacteria confers protection against bubonic plague (but not pneumonic plague) in most recipients for several months. Booster injections are necessary every six months. Vaccination should not be relied upon as the sole preventive measure. For more detailed information consult the AFPMB Technical Guide No. 40: Methods for Trapping and Sampling Small Mammals for Virologic Testing.

II. Vector Identification:

Lewis, R. 1967. The fleas (Siphonaptera) of Egypt, an illustrated and annotated key. Journal of Parisitology, 53(4): 867-885.

CDC Pictorial Keys to Arthropods, Reptiles, Birds, and Mammals of Public Health Significance: Fleas

III. Additional Resources:

Flea Morphology (BYU, Fleas of the World)

Note: Fleas and tissues from suspected reservoirs or humans may be submitted for plague analysis to the Centers for Disease Control and Prevention, National Center for Infectious Diseases, Division of Vector-borne Infectious Diseases, P.O. Box 2087, Foothills Campus, Fort Collins, Colorado 80522. Contact Centers for Disease Control and Prevention at (970) 221-6400 for additional information.

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Glossina spp.


Pregnant female tsetse fly. Credit: Geoffrey M. Attardo

Bionomics: Tsetse flies are obligate blood-sucking Dipterans of medical importance due to their ability to carry and transmit Trypanosomiasis, or sleeping sickness. They resemble house flies and typically have a size range of 8 mm to 17 mm. They're easily identifiable while resting through two characteristics: one wing is rested directly on top of the other and they have a lengthy proboscis which extends directly forward and is attached through a unique appendage to the bottom of their head. Female flies have a uterus in which a single egg hatches. This larva then feeds on the milk glands of the tsetse fly for 10-15 days. After this period, the fly deposits the now larger, third instar larva into soil. After burrowing into the ground, the larva pupates almost immediately and emerges into an adult fly three weeks or longer later. Both sexes of tsetse flies exclusively take blood meals to feed. One female can only produce eight-ten larva in ten to twelve day intervals, which allows their populations to be controlled relatively easily. Tsetse flies readily feed on humans as well as both wild and domestic animals, all of which are reservoirs for sleeping sickness parasites (trypanosomes). *Glossina sp.* are highly mobile insects who can travel up to 1 km per day making accurate modeling somewhat difficult. The bites of tsetse flies can be very painful and often result in a reaction on the bite site known as a trypanosomal chancre. The species that transmit sleeping sickness generally breed under trees near watering holes such as rivers and lakes, or in an open woodland when feeding off of larger animals. Tsetse flies are more active as biters during midday hours and their activity typically declines after sunset. Members of the *Morsitans*, or savanna, and *Palpalis*, or riverine, groups contain the majority of medically important species.

Medical Importance: Members of the *Palpalis* complex are the primary vector group of Trypanosomiasis in West Africa. *Glossina tachinoides*, *G. palpalis s.l.* and *G. morsitans submorsitans* are some the most significant vector species in this region.

Vector Surveillance and Suppression: The most effective efforts of control have typically been centered on the surrounding tsetse fly habitat such as the removal of wild game, clearing of forest land, and burning to prevent brush growth. More typical methods of spraying insecticides and trapping may lower local populations, but are not feasible means of eliminating the vectors as a whole. Population screening for Trypanosomiasis parasites is one of the main control strategies used as humans are significant disease reservoirs. Permethrin and other repellent have not been shown to be very effective against tsetse flies, however, they would aid in the prevention of Trypanosomiasis spread through mechanical means (other fly bites). Military personnel should minimize their contact with tsetse flies by wearing protective clothing, avoiding bush and woodland, and inspecting vehicles before they enter as tsetse flies are attracted to the movement and dust caused by vehicles in motion.

Vector Identification:

Hoppenheit, A., Murugaiyan, J., Bauer, B., Steuber, S., Clausen, P.H. and Roesler, U. (2013). Identificaiton of Tsetse (*Glossina* spp.) Using Matrix-Assisted Laser Desorption/Ionisation Time of Flight Mass Spectrometry. PLOS Neglected Tropical Diseases, 7(7).

Training Manual for Tsetse Control Personnel

Additional Resources:

WHO Tsetse Fly Profile

Brittanica Tsetse Fly Profile

BBC Tsetse Fly and Sleeping Sickness

CDC Prevention and Control

Tsetse Fly Module

Bogitsh, B.J., Carter, C.E. and Oeltmann, T.N. (2019). Human Parasitology (Fifth Edition). Elsevier, p. 1-360.

Isaac, C., Ciosi, M., Hamilton, A., et al. (2016). Molecular identification of different trypanosome species and subspecies in tsetse flies of northern Nigeria. Parasites & Vectors, 9:301.

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Simulium damnosum s.l.

Simulium damnosum female, photo cred: A. Renz.

Bionomics: After a bloodmeal, female black flies lay eggs on emergent vegetation along streams, or on logs and rocks that are splashed with water. Several masses of 150 to 500 eggs may be laid over a life span of 3 to 4 weeks. Eggs hatch in 2 to 3 days at temperatures of 25 to 30° C. Using caudal suckers and silken threads, black fly larvae attach to rocks in swift flowing streams, generally in mountainous areas of 300 to 1,200 m. They require relatively clean streams with high oxygen content. Larvae feed on small crustaceans, protozoa, algae, bacteria, and decaying bits of plants and animals suspended in the water. They progress through 6 to 9 (often 7) instars, and pupate 7 to 12 days after hatching, depending on temperature. Pupae are found in streams for about 1 to 2 weeks prior to emergence of adults. *Simulium damnosum* complex vectors are fierce biters that emerge in large numbers during the rainy season. Many generations can be produced as long as streams are flowing. Females often circle in swarms around the lower extremities of human hosts. They are persistent biters that feed primarily outside and during the day. Engorgement usually requires only a few minutes. Bites may cause extreme irritation and itching in human or animal hosts. In sensitive persons, black fly bites can cause an acute allergic response. These flies are anthropophilic but also feed on cattle. Black flies are exophilic and not noted for entering human structures. After feeding, black flies fly to nearby shaded sites or protective vegetation. Black flies are strong fliers that can travel many kilometers (5 to 10 km or more) from their home streams. It is estimated that strong winds could easily carry them an additional 5 to 10 km from their breeding sites. Because most suitable streams flow primarily during the rainy season, the seasonal distribution of black flies is usually short. Species from the *Simulium damnosum* complex would have their highest numbers in Niger where moving water is present such as in the southern portion of the country. Identification of species within the *S. damnosum* complex requires chromosomal analysis or molecular barcoding since they are morphologically identical.

Medical Importance: Members of the *Simulium damnosum* complex are the primary vectors of Onchocerciasis.

Vector Surveillance and Suppression: Control can rarely be achieved by directly attacking the adult black fly. Adults are susceptible to insecticides but are usually too widely dispersed for insecticidal spraying or fogging to achieve more than very temporary local control. Black fly populations are most concentrated in the immature aquatic stages. Control measures have been directed against black fly larvae with great success. Black fly larvae are susceptible to very low doses of many insecticides, including the biological control agent *Bacillus thuringiensis* (BTI). Aerial larviciding is usually necessary to treat rivers with extensive tributary systems. Reducing contact between black flies and military personnel is best achieved by using personal protective measures, such as wearing protective clothing and headgear and applying repellents. Control efforts have previously eradicated species such as *Simulium neavai*, Kenya's primary vector of Onchocerciasis in the past, from their country and could feasibly be implemented in other countries where river blindness is present.

Vector Identification:

Dang, P.T. & Peterson, B.V. 1980. Pictorial keys to the main species and species groups within the *Simulium damnosum* Theobald complex occurring in West Africa (Diptera: Simuliidae). Tropenmedizin and Parasitologie, 31(1): 117-120.

Morales-Hojas, R. & Krueger, A. 2009. The species delimitation problem in the Simulium damnosum complex, blackfly vectors of onchocerciasis. Medical and Veterinary Entomology, 23(3): 257-268.

Additional Resources:

Routledge, I., Walker, M., Cheke, R.A., Bhatt, S., Nkot, P.B., Matthewsw, G.A., Baleguel, D., Dobson, H.M., Wiles, T.L. and Basanez, M.G. (2018). Modelling the impact of larviciding on the population dynamics and biting rates of *Simulium damnosum* (*s.l.*): implications for vector control as a complementary strategy for onchocerciasis elimination in Africa. Parasites & Vectors, 11:316.

Hendy, A., Sluydts, V., Tushar, T., De Witte, J., Odonga, P., Loum, D., et al. (2017) Esperanza Window Traps for the collection of anthropophilic blackflies (Diptera: Simuliidae) in Uganda and Tanzania. PLoS Negl Trop Dis 11(6): e0005688

Adler, P.H., Cheke, R.A. and Post, R.J. (2010). Evolution, epidemiology, and population genetics of black flies (Diptera: Simuliidae). Infection, Genetics and Evolution, 10:846-865.

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Pediculus humanus Linnaeus, 1758

Bionomics: Human lice spend their entire life cycle (egg, 3 nymphal stages and adult) on the host. Eggs of body lice are attached to clothing at a rate of about 5 eggs per female per day. At 29 to 32° C, eggs hatch in 7 to 10 days. The maximum time eggs can survive unhatched is 3 to 4 weeks, which is important when considering the survival of lice in infested clothing and bedding. A blood meal is required for each of the 3 nymphal molts and for egg production in adults. The nymphal stages are passed in 8 to 16 days. Louse populations have the potential to double every 7 days. Adults live about 2 weeks and feed daily. Infestations of lice cause considerable irritation and scratching, which may lead to skin lesions and secondary infections. Body lice are commonly found in the seams and folds of clothing. Lice tolerate only a narrow temperature range and will abandon a dead host or one with a body temperature of 40° C or above. This contributes to the spread of lice and louse-borne disease. Human lice can survive without a host for only a few days.

Blood-engorged head lice (*Pediculus humanus capitis* de Geer).
Photo Credit: AFPMB: James L. Occi

Medical Importance: Human lice are known vectors of louse-borne relapsing fever and epidemic typhus.

Vector Surveillance and Suppression: Surveillance for body lice consist of examining individuals and their clothing for lice or nits (eggs). Body louse infestations have declined with higher standards of living, although infestations are still common in some populations. Military personnel should avoid close personal contact with infested persons and their belongings, especially clothing and bedding. Dry cleaning or laundering clothing or bedding in hot water (55° C for 20 minutes) will kill eggs and lice. Control of epidemics requires mass treatment of individuals and their clothing with effective insecticides. The permethrin-treated uniform is extremely effective against lice. Since lice cannot survive away from the human host, application of insecticides to buildings, barracks or other living quarters is not necessary.

Vector Identification:

University of Florida, Entomology and Nematology, Featured Creatures: Body Louse

CDC Pictorial Keys to Arthropods, Reptiles, Birds, and Mammals of Public Health Significance: Lice

Additional Resources:

CDC: Pediculosis Background

Vector Base

Ugbomoiko, U.S., Speare, R. & Heukelbach, J. (2008). Self-Diagnosis of Head Lice Infestation in Rural Nigeria as a Reliable Rapid Assessment Tool for Pediculosis. The Open Dermatology Journal, 2:95-97.

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Personal Protective Measures

Field Uniform: Personal protective measures are the first line of defense against arthropod-borne disease and, in some cases, may be the only protection for deployed military personnel. Proper wearing of the uniform and appropriate use of repellents can provide high levels of protection against blood-sucking arthropods. The uniform fabric provides a significant mechanical barrier to mosquitoes and other blood-sucking insects. Therefore, the uniform should be worn to cover as much skin as possible if weather and physical activity permit. Proper wearing of the field uniform is essential to minimize skin exposure (Figure 2-1). If the risk of heat stress is a factor in a particular environment, common sense or advice from medical or Preventive Medicine personnel should dictate when the following recommendations are not practical:

1. Tuck pant legs into boots or into socks. This forces non-flying pests, such as ticks, chiggers, stinging ants and spiders, to climb up the outside of the pant legs, thus decreasing access to the skin and increasing the likelihood of their being seen.
2. Roll sleeves down and close the collar to help protect the arms and neck from arthropod attack. This is especially important in malaria-endemic regions when Anopheles species bite from dusk until dawn.
3. It is difficult for pests to bite through the uniform fabric unless it is pulled tightly against the skin. Therefore, the uniform should be worn loosely, with an undershirt worn underneath the coat to act as an added barrier. The undershirt should be tucked into the pants to decrease access by crawling arthropods at the waistline. Mosquitoes can easily bite through tight-fitting material such as that used for the combat uniform.
4. The field cap and its brim help protect the head and face. Some biting insects tend to avoid the shaded area of the face under the cap's brim.
5. Uniforms that are treated with permethrin provide protection only on the covered portion of the body. Mosquitoes will still readily feed on the hands, neck and head. It is essential to apply an approved insect repellent to exposed body surfaces. Reapplication is advised according to the label.

For more information on personal protective measures, consult AFPMB Technical Guide No. 36: Personal Protective Measures Against Insects and Other Arthropods of Military Significance.

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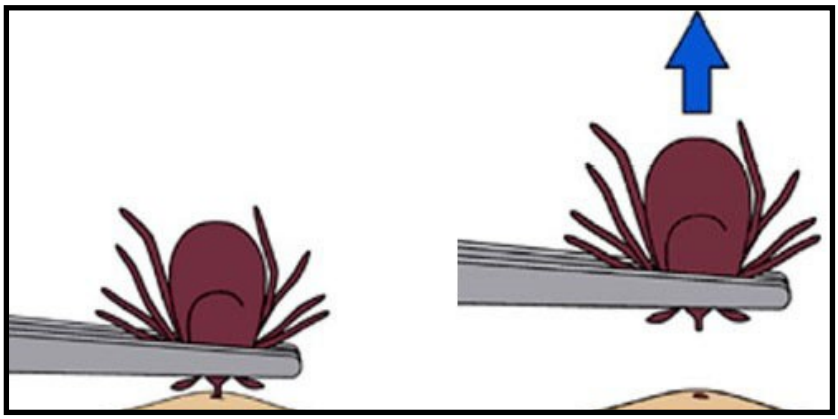
Personal Protective Measures

When personnel are operating in tick-infested areas, they should tuck their pant legs into their boots to prevent access to the skin by ticks, chiggers, and other crawling arthropods. They should also check themselves frequently for ticks and immediately remove any that are found. If a tick has attached, seek assistance from medical authorities for proper removal or follow these guidelines from TIM 36,

1. Grasp the tick's mouthparts where they enter the skin, using pointed tweezers.

2. Pull out slowly and steadily with gentle force. (A) Pull in the reverse of the direction in which the mouthparts are inserted, as you would for a splinter. (B) Be patient – The long, central mouthpart (called the hypostome) is inserted in the skin. It is covered with sharp barbs, sometimes making removal difficult and time consuming. (C) Many hard ticks secrete a cement-like substance during feeding. This material helps secure their mouthparts firmly in the flesh and adds to the difficulty of removal. (D) It is important to continue to pull steadily until the tick can be eased out of the skin. (E) Do not pull back sharply, as this may tear the mouthparts from the body of the tick, leaving them embedded in the skin. If this happens, don't panic. Embedded mouthparts are comparable to having a splinter in your skin. However, to prevent secondary infection, it is best to remove them. Seek medical assistance if necessary. (F) Do not squeeze or crush the body of the tick because this may force infective body fluids through the mouthparts and into the wound. (G) Do not apply substances like petroleum jelly, fingernail polish remover, repellents, pesticides, or a lighted match to the tick while it is attached. These materials are either ineffective or, worse, may agitate the tick and cause it to salivate or regurgitate infective fluid into the wound site. If tweezers are not available, grasp the tick's mouthparts between your fingernails, and remove the tick carefully by hand. Be sure to wash your hands especially under your fingernails -- to prevent possible contamination by infective material from the tick.



3. Following removal of the tick, wash the wound (and your hands) with soap and water and apply an antiseptic.

4. Save the tick in a jar, vial, small plastic bag, or other container for identification should you later develop disease symptoms. Preserve the tick by either adding some alcohol to the jar or by keeping it in a freezer. Storing a tick in water will not preserve it. Identification of the tick will help the physician's diagnosis and treatment, since many tick-borne diseases are transmitted only by certain species.

5. Discard the tick after one month; all known tick-borne diseases will generally display symptoms within this time period. Newly developed repellents provide military personnel with unprecedented levels of protection. An aerosol formulation of permethrin (NSN 6840-01-278-1336) can be applied to the uniform according to label directions, but not to the skin. This will impart both repellent and insecticidal properties to the uniform material that will be retained through numerous washings. An extended formulation lotion of N, N-diethyl-m-toluamide (deet) (NSN 6840-01-284-3982) has been developed to replace the 2 oz. bottles of 75% deet in alcohol. This lotion contains 33% active ingredient. It is less irritating to the skin, has less odor and is generally more acceptable to the user. A properly worn Battle Dress Uniform (BDU) impregnated with permethrin, combined with use of extended duration deet on exposed skin, has been demonstrated to provide nearly 100% protection against a variety of blood-sucking arthropods. This dual strategy is termed the DoD INSECT REPELLENT SYSTEM. In addition, permethrin may be applied to bednets, tents, and other field items as appropriate. Complete details regarding these and other personal protective measures are provided in TIM 36, Personal Protective Techniques Against Insects and Other Arthropods of Military Significance (1996).

For more information on personal protective measures, consult AFPMB Technical Guide No. 36: Personal Protective Measures Against Insects and Other Arthropods of Military Significance.

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Table of Arboviruses

Abbreviation	Arbovirus	Abbreviation	Arbovirus
AINOV	Aino Virus	AgDNV	Anopheles gambiae Densovirus
AnCV	Anopheles C Virus	AngFV	Anopheles gambiae Flavivirus
AToV	Anopheles Totivirus	AHSV	African Horseickness Virus
AMTV	Arumowot Virus	APEUV	Apeu Virus
APV	Agua Preta Virus	BAGV	Bagaza Virus
BAV	Banna Virus	BARV	Barur Virus
BBKV	Babanki Virus	BEFV	Bovine Ephemeral Fever Virus
BGIV	Bangui Virus	BIRV	Birao Virus
BOUV	Bouboui Virus	BOZOV	Bozo Virus
BSQV	Bussuquara Virus	BUNV	Bunyamwera Virus
BWAV	Bwamba Virus	CHAOV	Chaoyang Virus
CHIKV	Chikungunya Virus	CHPV	Chandipura Virus
CPV	Coastal Plains Virus	CTFV	Colorado Tick Fever Virus
CVOV	Calovo Virus	CVV	Cache Valley Virus
CWV	Cape Wrath Virus	DENV 1-3	Dengue Virus 1, Dengue Virus 2, Dengue Virus 3
EEEV	Easter Equine Encephalomyelitis Virus	EHDV	Epizootic Hemorrhagic Disease of Deer Virus
FMV	Fort Morgan Virus	GERV	Germiston Virus
GFV	Gabek Forest Virus	GROV	Guaroa Virus
HPV	Hart Park Virus	IKV	Issyk-Kul Virus
ILEV	Ilesha Virus	ILHV	Ilheus Virus

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Table of Arboviruses & Parasites

Abbreviation	Arbovirus	Abbreviation	Arbovirus
INGV	Inwavuma Virus	ISFV	Isfahan Virus
ITV	Israel Turkey Meningoencephalitis Virus	IRIV	Irituia Virus
JAPV	Japanaut Virus	JBEV	Japanese B Encephalitis Virus
JCV	Jamestown Canyon Virus	JEV	Japanese Encephalitis Virus
JOIV	Joinjakaka Virus	KAIV	Kaikalur Virus
KEYV	Keystone Virus	KOTV	Kotonkan Virus
KOWV	Kowanyama Virus	KRIV	Kairi Virus
KUNV	Kunjin Virus	LACV	La Crosse Virus
LCV	Lake Clarendon Virus	LMV	Las Maloyas Virus
MAGV	Maguari Virus	MALV	Malakai Virus
MBGV	Marburg Virus	MCOV	Marco Virus
MEBV	Mount Elgon bat Virus	MIDV	Middleburg Virus
MTBV	Marituba Virus	MUCV	Mucambo Virus
MVEV	Murray Valley Encephalitis Virus	NAVV	Navarro Virus
NDOV	Nyando Virus	NDUV	Ndumu Virus
NEGV	Negishi Virus	NEPV	Nepuyo Virus
NKOV	Nkolbisson Virus	NOLAV	Nola Virus
NRIV	Nigari Virus	NTAV	Ntaya Virus
OCKV	Ockelbo Virus	OLIV	Olifantsylei Virus
ONNV	O'nyong-nyong Virus	ORIV	Oriboca Virus

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Table of Arboviruses & Parasites

Abbreviation	Arbovirus	Abbreviation	Arbovirus
OROV	Oropuche Virus	ORUV	Orungo Virus
PARAV	Para Virus	PGAV	Pongola Virus
PGAV	Pongola Virus	POTV	Potosi Virus
PUCV	Puchong Virus	RESV	Restan Virus
ROCV	Rocio Virus	RRV	Ross River Virus
RVFV	Rift Valley Fever Virus	SAGV	Sagiyama Virus
SFSV	Sandfly Fever Sicilian Virus	SFV	Semliki Forest Virus
SHOV	Shokwe Virus	SHUV	Shuni Virus
SINV	Sindbis Virus	SLEV	Saint Louis Encephalitis Virus
SPOV	Spondweni Virus	STRV	Stratford Virus
TAHV	Tahyna Virus	TANV	Tanga Virus
TSUV	Tsuruse Virus	TURV	Turlock Virus
TVTV	Trivittatus Virus	TYUV	Tyuleniy Virus
UMBV	Umbre Virus	USUV	Usutu Virus
VFV	Virgin River Virus	VEEV	Venezuelan Equine Encephalitis Virus
VSAV	Vesicular Stomatitis, Alagoas Serotype Virus	VSIV	Vesicular Stomatitis, Indiana Serotype Virus
VSNJV	Vesicular Stomatitis, New Jersey Serotype Virus	WANV	Wanowrie Virus
WNV	West Nile Virus	WEEV	Western Equine Encephalomyelitis Virus
WSLV	Wesselsbron Virus	YAOV	Yaounde Virus
YATAV	Yata Virus	YFV	Yellow Fever Virus
ZEGV	Zegla Virus	ZIKV	Zika Virus

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Table of Parasites

Parasite	Associated Disease	Parasite	Associated Disease
Brugia malayi	Lymphatic filariasis	*Brugia pahangi*	Filariasis
Brugia patei	Filariasis	*Dirofilaria immitis*	Dirofilariasis
Dirofilaria repens	Dirofilariasis	*Plasmodium cynomol-*	Malaria
Plasmodium falcipa-rum	Human malaria	*Plasmodium gallina-ceum*	Malaria
Plasmodium lophurae	Malaria	*Plasmodium malariae*	Human malaria
Plasmodium ovale	Human malaria	*Plasmodium prae-*	Malaria
Plasmodium relictum	Malaria	*Plasmodium vivax*	Human malaria
Wuchereria bancrofti	Lymphatic/ Bancroftian filariasis		

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Bionomics Table: Mosquito Vectors of Niger

Species Name	Medical Importance	Biting Times	Host Preference	Feeding Behavior	Resting Behavior
Aedes (*Stg.*) *aegypti* (Linnaeus, 1762)	DENV, CHIKV, ZIKV, YFV	06:00-18:00	Primarily Anthropophilic	Exophagic and Endophagic	Exophilic and Endophillic
Aedes (Fre.) vittatus (Bigot, 1861)	DENV, CHIKV, ZIKV, YFV	No data	Anthropophilic	No data	No data
Anopheles (*Cel.*) *arabiensis* Patton, 1905	Malaria	19:00-03:00	Primarily Zoophilic but known to be Anthropophilic on occasion	Exophagic	Primarily Exophillic but known to be Endophillic on occasion
Anopheles (Cel.) funestus s.s. Giles, 1900	Malaria	22:00-06:00	Anthropophilic	Endophagic	Endophilic
Anopheles (Cel.) gambiae s.s. Giles, 1902	Malaria	18:00-06:00	Anthropophilic	Primarily Endophagic	Endophilic
Anopheles (Cel.) moucheti Giles, 1923	Malaria	18:00-06:00	Anthropophilic	Endophagic	Endophilic
Anopheles (Cel.) nili s.s. (Theobald, 1904)	Malaria	18:00-06:00	Anthropophilic and Zoophilic	Exophagic and Endophagic	Endophilic
Anopheles (Cel.) pharoensis s.s. Theobald, 1901	Malaria	18:00-06:00	Primarily Zoophilic but opportunistically Anthropophilic	No data	No data
Anopheles (Cel.) multicolor Cambouliu, 1902	Malaria	No data	No data	No data	Primarily Exophilic but known to be Endophilic on occasion
Culex (Cux.) univittatus Theobald, 1901	WNV, SINV	18:00-06:00	Anthropophilic and Zoophilic	Exophagic and Endophagic	Exophilic and Endophillic
Culex (*Cux.*) *quinquefasciatus* Say, 1823	WNV	18:00-06:00	Primarily Anthropophilic and Zoophilic	Exophagic and Endophagic	Exophilic and Endophillic
Mansonia (Mnd.) uniformis (Theobald, 1901)	RVFV, *Wuchereria malayi*	19:00-20:00	Primarily Zoophilic but opportunistically Anthropophilic	Exophagic	No data

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Bionomics Table: Tick Vectors of Niger

Species Name	Medical Importance	Life Cycle	Host Preference	Oviposition
Amblyomma variegatum Fabricius 1794	Crimean-Congo Hemorrhagic Fever (CCHF)	This species is a three-host tick.	Sheep and cattle, and occasionally humans	No data
Hyalomma dromedarii Koch, 1844	Crimean-Congo Hemorrhagic Fever (CCHF)	This species may be either a two- or three-host tick.	Camels, cattle, goats, dogs, small mammals, lizards and occasionally humans	*Hyalomma* sp. ticks, the number of eggs laid is variable, ranging from hundreds in rodent burrows to thousands on open ground or vegetation. Eggs usually hatch within 30 days.
Hyalomma truncatum Koch, 1844	Crimean-Congo Hemorrhagic Fever (CCHF)	This species is usually a two-host tick that is found in floodplains in semi-deserts and steppes, or vegetated hillsides and mountainsides are preferred habitats.	Cattle, camels and sheep, immature stages tend to parasitize ground-feeding birds	*Hyalomma* sp. ticks, the number of eggs laid is variable, ranging from hundreds in rodent burrows to thousands on open ground or vegetation. Eggs usually hatch within 30 days.
Rhipicephalus sanguineous (Latreille, 1806)	Crimean-Congo Hemorrhagic Fever (CCHF), Boutonneuse Fever	This species is a three-host tick that is prevalent in urban areas because of its close association with dogs.	Dogs but also feeds on camels, gerbils and, occasionally, humans	*Rhipicephalus* sp. ticks, lay hundreds of eggs, generally in the dens of host animals, especially canines.
Hyalomma impeltatum Schulze & Schlottke, 1930	Crimean-Congo Hemorrhagic Fever (CCHF)	This species is usually a two-host tick that lives in scattered foci of semi-desert, savanna, and steppe biotopes.	Camels, cattle, rodents, hares, ground birds and other large domestic animals	*Hyalomma* sp. ticks, the number of eggs laid is variable, ranging from hundreds in rodent burrows to thousands on open ground or vegetation. Eggs usually hatch within 30 days.
Hyalomma rufipes Koch, 1844	Crimean-Congo Hemorrhagic Fever (CCHF), Tick Typhus	This species is a two-host tick.	Cattle, sheep, goats, horses and wild unglates.	*Hyalomma* sp. ticks, the number of eggs laid is variable, ranging from hundreds in rodent burrows to thousands on open ground or vegetation. Eggs usually hatch within 30 days.

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