# Vector Hazard Report:

## Insecticide Resistance and Malaria Vectors of Ghana


Notes on the biology, distribution and identification of malaria vectors of Ghana and reported insecticide resistance.

**Last Updated by David Pecor September 2021**

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# Preface

## Vector Hazard Reports are a product of the Walter Reed Army Institute of Research / Walter Reed Biosystematics Unit (WRAIR-WRBU)

This document provides summarized information on the vectors of malaria reported from Ghana as of September, 2021. Information related to the identification, distribution, medical importance, control and surveillance of malaria vector species are included. 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. View the Vector Hazard Report Quick Guide on page 3 for real-time threat assessment resources, quick navigation to vector-borne disease travel alerts in Ghana and resources for vector identification and the most current insecticide resistance surveillance data. Further details on each vector species covered in this report are available via the WRBU website or by selecting the 'WRBU Species Profile' links on each species summary. The target audience for this document are commanders, medical planners, preventive medicine personnel, and particularly medical entomologists. For each vector species threat included in this report, the following information is provided:

- **Current Taxonomy**
- **Bionomics**
- **Vector Status**
- **Identification Tools**
- **Surveillance and Control Strategies**
- **Additional Resources**

Insecticide resistance testing is generally performed by either a CDC or WHO bottle assay which are experiments designed to expose mosquitoes to different pesticides and recording the diagnostic dose (DD) and diagnostic time (DT). Some IR testing involves scrrening extracted DNA from mosquito specimens to identify knock-down resistance genes, and other genetic mutations (kdr-w, kdr-e and ace-1) by PCR. IR testing results from all the aforementioned methods are included in this report from mosquito specimens collected in Ghana and are compiled from the following sources:

- **VectorMap**
- **VectorBase**
- **IR Mapper**

### Disclaimer:

Material has been reviewed by the Walter Reed Army Institute of Research. There is no objection to its presentation and/or publication. The opinions or assertions contained herein are the private views of the author, and are not to be construed as official, or as reflecting true views of the Department of the Army or the Department of Defense.

# Vector Hazard Report Quick Guide: Ghana

| Real-Time Threat Assessment Resources<br><br>Visit these websites for regularly updated information about current vector-borne disease threats and questions about insecticide use |
|---|
| U.S. Dept. of State Travel Alerts |
| Health.mil Reports |
| CDC Current Outbreaks List |
| WHO Outbreak News |
| HealthMap Outbreaks |
| DoD Pesticide Hotline & Pesticide Use Reporting |

| Additional Resources |
|---|
| WHO Country Profile: Ghana |
| CDC Travelers Guide: Ghana |
| DoD Insect Repellent System |

## Vector Identification Resources

| Vector | Source |
|---|---|
| Mosquito | WRBU Pictorial Key to the Medically Important Mosquitoes of AFRICOM<br><br>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. |

| Insecticide Resistance Resources |
|---|
| APHC Pesticide Use and Resistance Monitoring |
| Test procedures for insecticide resistance monitoring in malaria vector mosquitoes (WHO) |
| Bottle Assay for Insecticide Resistance (CDC) |

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# Background

## Malaria in Ghana

According to the World Health Organization (WHO), 2% of global malaria cases and 3% of global malaria deaths occur in Ghana. However, Ghana has made progress since 2016 to reduce malaria cases by over 30% by implementing a combination of insecticides, rapid diagnostic testing, anti-malaria drugs and increased training for health workers to diagnose and treat malaria.

The entire population faces some risk of malaria transmission throughout the year. Generally, seasonality of malaria transmission differs between the north and south. In the north, there is a longer season from July to November, except in the farthest regions to the north where this season is only 3 to 4 months long. In the south, malaria transmission peaks at two points during the year, from May to June and again from October to November.

## Insecticide Resistance in Ghana

In Ghana, the most common methods used to reduce malaria cases are indoor residual spraying (IRS) and long lasting insecticide treated Nets (LLITN). Although these interventions have proven extremely effective at reducing overall malaria burden, they have also proven an effective way to increase insecticide resistance in local mosquito populations. Vector control puts selection pressure on mosquito populations and resistance is favored when pressure is applied via insecticide applications.

Options for insecticide use are also limited, with only 4 classes of insecticides currently widely available (organochlorines, organophosphates, pyrethroids and carbamates). Without the use of alternative pesticides or non-chemical vector control methods, resistance levels will increase overtime, reducing the effectiveness of malaria reduction campaigns. Of particular concern are rising levels of pyrethroids as this class is most commonly used for LLITN and treated fabrics. Further compounding the issue, insecticides used to prevent agriculture pests are also impacting mosquito populations and contributing to overall resistance rates.

## References


USAID President's Malaria Initiative FY 2020 Ghana Malaria Operational Plan

World Health Organisation (2019). World Malaria Report 2020


For additional information about malaria surveillance and suppression consult the US Army Public Health Command (APHC) and Armed Forces Pest Management Board (AFPMB):

- All APHC Resources
- APHC TG 336—Malaria Field Guide
- APHC FactSheet: Malaria
- All AFPMB Technical Guides
- AFPMB TG 13—Dispersal of Ultra Low Volume (ULV) Insecticides by Cold Aerosol and Thermal Fog Ground Application Equipment

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# Vectors of Malaria: *Anopheles* spp.

**Vector Surveillance and Suppression:** $CO_2$ baited light traps are commonly used to collect *Anopheles* mosquitoes, but not all *Anopheles* spp. are detected in light trap collections. Animal or human baited traps are quite useful for determining feeding preferences of local mosquito populations, however may require the use of human use protocols. Adults are often collected from indoor and outdoor resting sites by aspiration. Systematic larval dipping provides valuable insights into species-specific habitat that can be used to inform larval breeding site reduction plans. The Armed Forces Pest Management Board (AFPMB) advises that effective malaria suppression requires the 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.

### Vector Identification:

- Glick, J. I. (1992). *Illustrated key to the female Anopheles of southwestern Asia and Egypt (Diptera: Culicidae)*. Walter Reed Biosystematics Unit Washington DC.
- 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.

### Additional Resources:

- 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).
- Wilkerson, R. C., Linton, Y. M., & Strickman, D. (2021). *Mosquitoes of the World (Vol. 1 & 2)*. Johns Hopkins University Press.

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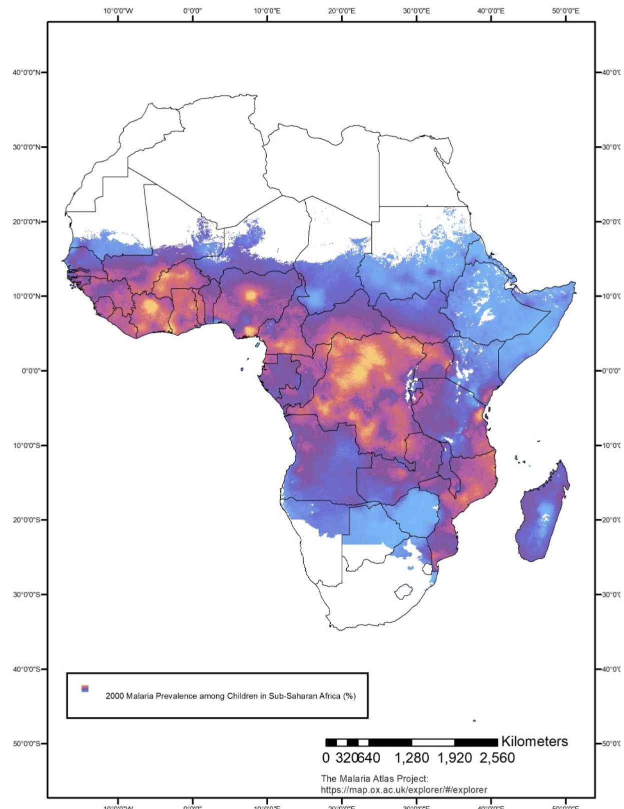
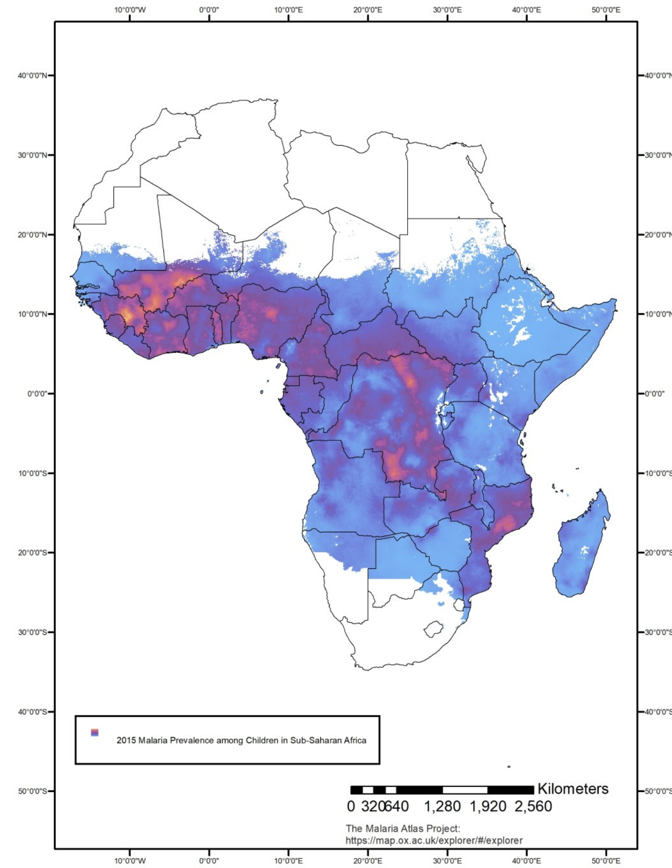
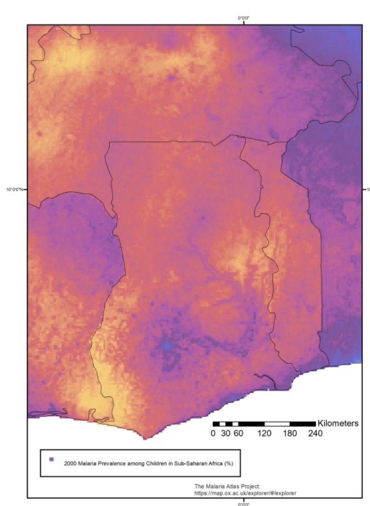
# Malaria Distribution: Africa

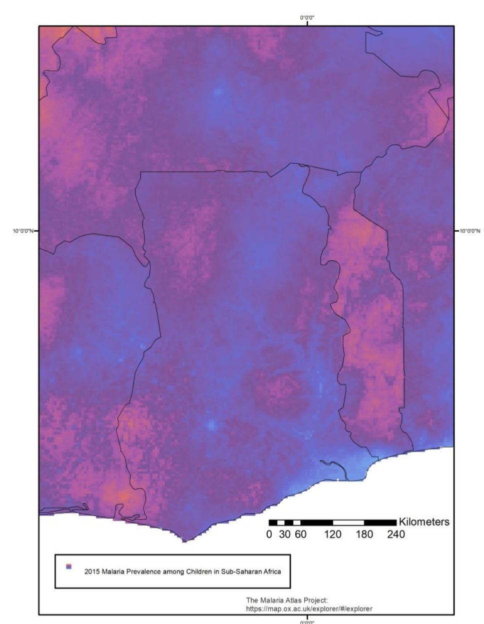
**Malaria cases have declined across Africa in recent decades, but it remains a significant threat.**




Malaria incidence among children (2-15) from 2000 compared to 2015, maps from: Malaria Atlas Project. Source: [Cibulskis, R. E., Alonso, P., Aponte, J., Aregawi, M., Barrette, A., Bergeron, L., ... & Williams, R. (2016). Malaria: global progress 2000–2015 and future challenges. *Infectious Diseases of Poverty*, 5(1), 1-8.]

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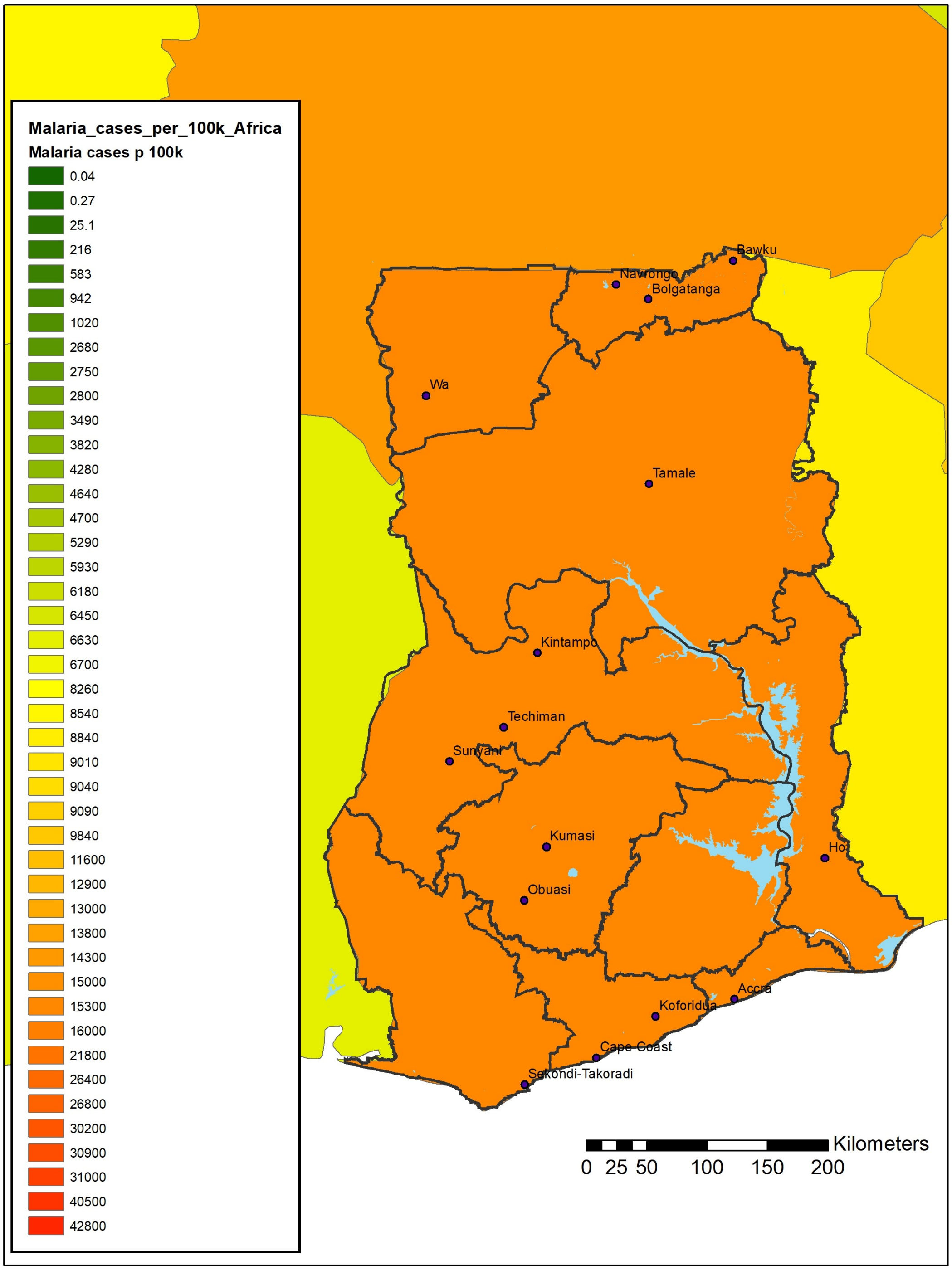
# Malaria Distribution: Ghana




Malaria cases per 100k people, from: [WHO World Malaria Report, 2020.](#)

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# *Anopheles* (*Cellia*) *gambiae* Giles, 1902

## Notes on Taxonomy:

The Gambiae Complex is comprised of 8 formally described species (*Anopheles amharicus*, *An. arabiensis*, *An. coluzzii*, *An. gambiae* s.s., *An. melas*, *An. merus*, and *An. quadriannulatus*). Members of the complex can be difficult to identify to species-level without molecular identification tools. Due to this limitation, much of the literature and surveillance data available only identifies these specimens as *Anopheles gambiae* s.l. The nominotypical member of the complex, *An. gambiae*, has been widely detected in Ghana, as well as *An. arabiensis*, *An. coluzzii* and *An. melus*.

## 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.

## Medical Importance:

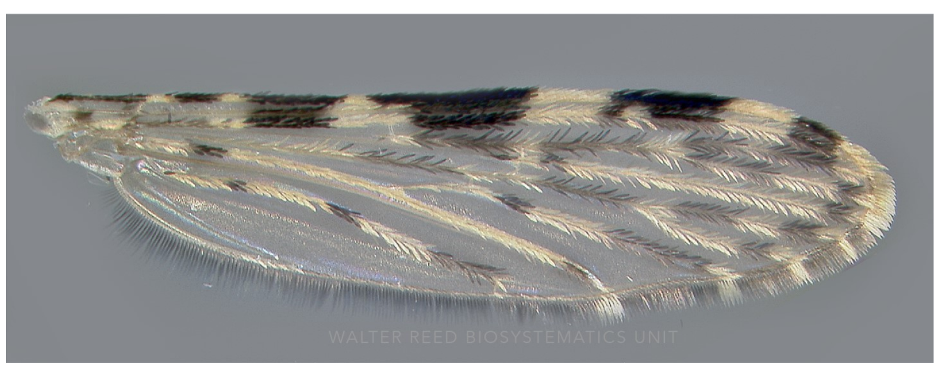
*Anopheles gambiae* is a vector of *Plasmodium falciparum*, *P. gallinaceum*, *P. malariae* and *P. ovale.*

## WRBU Species Profile


- Gillies, M.T., & de Meillon, B. (1968). The Anophelinae of Africa, south of the Sahara (Ethiopian zoogeographical region). *Publications of the South African Institute for Medical Research*, 54, 1–343.

- Yawson, A. E., Weetman, D., Wilson, M. D., & Donnelly, M. J. (2007). Ecological zones rather than molecular forms predict genetic differentiation in the malaria vector *Anopheles gambiae* ss in Ghana. *Genetics*, 175 (2), 751-761.



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# *Anopheles* (*Cellia*) *arabiensis* Patton, 1905

## Bionomics:

*Anopheles 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, their 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:

*Anopheles arabiensis* is a vector of *Plasmodium falciparum* and *P. vivax*.

## WRBU Species Profile

- 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.

# *Anopheles* (*Cellia*) *coluzzii* Coetzee & Wilkerson 2013

## Bionomics:

*Anopheles coluzzii* larvae are found in more permanent breeding sites often the result of human activity (agriculture, ditches, etc.). In Burkina Faso, larger numbers were reported during the raining season vs the cold, dry season.


## Medical Importance:

*Anopheles coluzzii* is a vector of *Plasmodium falciparum, P. vivax* and *P. berghei*.

## WRBU Species Profile

- Coetzee, M., Hunt, R. H., Wilkerson, R., Della Torre, A., Coulibaly, M. B., & Besansky, N. J. (2013). *Anopheles coluzzii* and *Anopheles amharicus*, new members of the *Anopheles gambiae* complex. *Zootaxa*, *3619*(3), 246-274.
- Lutz, E. K., Ha, K. T., & Riffell, J. A. (2020). Distinct navigation behaviors in *Aedes*, *Anopheles* and *Culex* mosquito larvae. *Journal of Experimental Biology*, 223(7).
- Mouhamadou, C. S., de Souza, S. S., Fodjo, B. K., Zoh, M. G., Bli, N. K., & Koudou, B. G. (2019). Evidence of insecticide resistance selection in wild *Anopheles coluzzii* mosquitoes due to agricultural pesticide use. *Infectious Diseases of Poverty*, 8(1), 1-8.

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# *Anopheles* (*Cellia*) *melas* (Theobald, 1903)


## Bionomics:

*Anopheles melas* larvae are found in coastal, saltwater pools and mangrove swamps. In Senegal, *An*. *melas* were observed to feed only a short distance from the larval breeding site. This study also characterized An. melas as more zoophilic and exophilic than *An*. *gambiae* s.s.

## Medical Importance:

*Anopheles melas* is a vector of *Plasmodium falciparum*.

## WRBU Species Profile


- Bryan, J.H. (1980) Use of palpal ratio and the number of pale bands on the palps in separating *Anopheles gambiae* Giles s.s. and *Anopheles melas* Theobald (Diptera: Culicidae). *Mosquito Systematics*, 12, 155–163.

- Fontenille, D., Lochouarn, L., Diatta, M., Sokhna, C., Dia, I., Diagne, N., ... & Trape, J. F. (1997). Four years' entomological study of the transmission of seasonal malaria in Senegal and the bionomics of *Anopheles gambiae* and *An. arabiensis*. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *91*(6), 647-652.


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# *Anopheles* (*Cellia*) *funestus* Giles, 1900

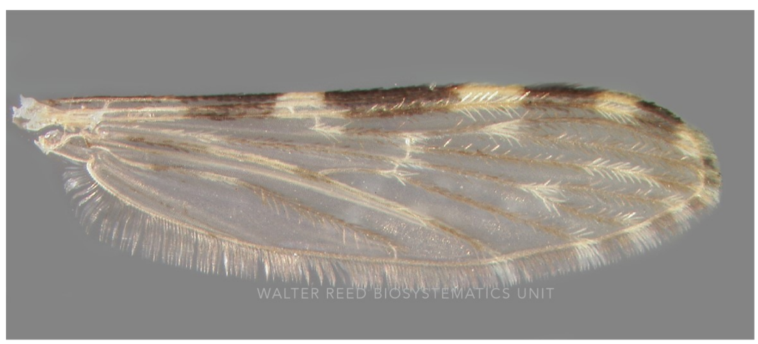

## Bionomics:

In most parts of its range, *Anopheles funestus* 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. It is one of the most anthropophilic mosquitoes known. *Anopheles fumestus* is also strongly endophilic, resting indoors after blood meals. The great bulk of feeding takes place inside houses after 22:00h up to dawn with peak biting between 0300 to 0500.

## Medical Importance:

*Anopheles funestus* is a vector of *Plasmodium falciparum* and *P. vivax.*

## WRBU Species Profile



- Okoye, P. N., Brooke, B. D., Koekemoer, L. L., Hunt, R. H., & Coetzee, M. (2008). Characterisation of DDT, pyrethroid and carbamate resistance in *Anopheles funestus* from Obuasi, Ghana. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *102*(6), 591-598.

- Riveron, J. M., Osae, M., Egyir-Yawson, A., Irving, H., Ibrahim, S. S., & Wondji, C. S. (2016). Multiple insecticide resistance in the major malaria vector Anopheles funestus in southern Ghana: implications for malaria control. *Parasites & Vectors*, *9*(1), 1-9.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# *Anopheles* (*Cellia*) *brunnipes* (Theobald, 1910)

## Bionomics:

*Anopheles brunnipes* is rarely encountered in relation to other *Anopheles* spp. occurring in West Africa. It has not been formally incriminated as a malaria vector, however specimens identified as *An. brunnipes* have been found with salivary infections of *Plasmodium* spp.

## Medical Importance:

*Anopheles brunnipes* is a suspected vector of *Plasmodium* spp.

## WRBU Species Profile

## References:


- Wanson, M., & Berteaux, M. (1944). The Infactivity of *Anopheles* (*Neocellia*) *brunnipes* Theobald. *East African Medical Journal*, *21*(9), 272-3.
- Davey, T. H. (1941). The larva and pupa of *Anopheles brunnipes* Theobald. *Annals of Tropical Medicine & Parasitology*, *35*(1), 5-8.
- Coene, J. (1993). Malaria in urban and rural Kinshasa: the entomological input. *Medical and Veterinary Entomology*, *7*(2), 127-137.


# *Anopheles* (*Anopheles*) *coustani* Laveran, 1900

## Bionomics:

*Anopheles coustani* is generally regarded as primarily zoophilic, however, *An. coustani* has been observed to opportunistically feed on humans and play a role in malaria transmission during the rainy season when population numbers peak. Larvae have been collected in swamps, irrigation ditches and drainage pools.

## Medical Importance:

*Anopheles coustani* is a vector of *Plasmodium falciparum.*

## WRBU Species Profile


- Fornadel, C. M., Norris, L. C., Franco, V., & Norris, D. E. (2011). Unexpected anthropophily in the potential secondary malaria vectors *Anopheles coustani* sl and *Anopheles squamosus* in Macha, Zambia. *Vector-borne and Zoonotic Diseases*, 11 (8), 1173-1179.
- Kenea, O., Balkew, M., & Gebre-Michael, T. (2011). Environmental factors associated with larval habitats of anopheline mosquitoes (Diptera: Culicidae) in irrigation and major drainage areas in the middle course of the Rift Valley, central Ethiopia. *Journal of Vector Borne Diseases*, *48*(2), 85.


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# *Anopheles* (*Cellia*) *demeilloni* Evans, 1933

## Bionomics:

Larvae of *An*. *demeilloni* have been collected in streams and natural ground pools. Adult females are primarily exophagic and are collected in far less numbers compared to *An*. *gambiae* s.l. and *An*. *funestus* s.l.

## Medical Importance:

*Anopheles demeilloni* is a vector of *Plasmodium falciparum.*

## WRBU Species Profile


- Gone, T., Balkew, M., & Gebre-Michael, T. (2014). Comparative entomological study on ecology and behaviour of Anopheles mosquitoes in highland and lowland localities of Derashe District, southern Ethiopia. *Parasites & Vectors*, 7(1), 1-10.


# *Anopheles* (*Cellia*) *freetownensis* Evans, 1925

## Medical Importance:

*Anopheles freetownensis* is a vector of *Plasmodium falciparum* and *P. vivax.*

## WRBU Species Profile


- Kyalo, D., Amratia, P., Mundia, C. W., Mbogo, C. M., Coetzee, M., & Snow, R. W. (2017). A geo-coded inventory of anophelines in the Afrotropical Region south of the Sahara: 1898-2016. *Wellcome Open Research*, 2.


# *Anopheles* (*Cellia*) *hancocki* Edwards, 1929

## Bionomics:

*Anopheles hancocki* females will readily feed on humans indoors but opportunistically on other mammal hosts. Larvae have been collected in natural water sources in low-lying areas such as lakes or swamps.

## Medical Importance:

*Anopheles hancocki* is a vector of *Plasmodium falciparum*.

## WRBU Species Profile


- Tchuinkam, T., Simard, F., Lélé-Defo, E., Téné-Fossog, B., Tateng-Ngouateu, A., Antonio-Nkondjio, C., ... & Awono-Ambéné, H. P. (2010). Bionomics of Anopheline species and malaria transmission dynamics along an altitudinal transect in Western Cameroon. *BMC Infectious Diseases*, *10*(1), 1-12.
- De Meillon, B. (1947b). The Anophelini of the Ethiopian geographical region. *Publications of the South African Institute for Medical Research*, *10*(49), 1–272.


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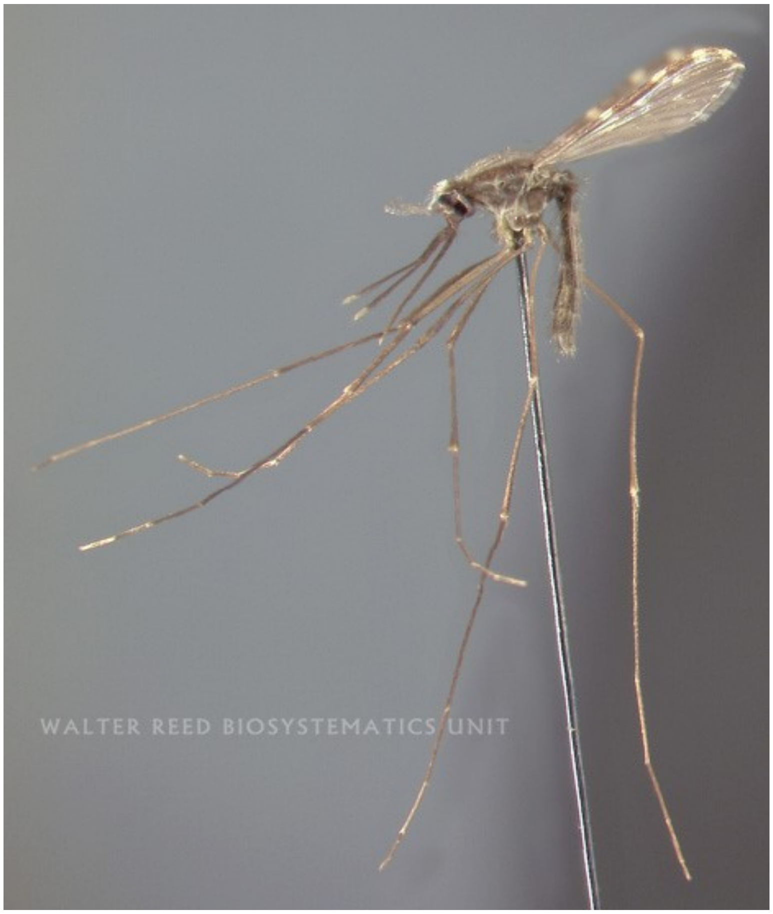
# *Anopheles* (*Cellia.*) *nili* (Theobald, 1904




## Notes on Taxonomy:

The Nili Complex is made up of 4 formally described species (*An. nili*, *An. carnevalei*, *An. ovengensis* and *An. somalicus*). *Anopheles nili* s.s. has been reported from Ghana with other members (*An. somalicus* and *An. carnevalei*) also reported, but not suspected to play a major role in malaria transmission.

## 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. It is known to be an anthropophilic species biting man readily indoors and outdoors and frequently resting indoors by day. Other members of this complex are known to be forest feeders who are primarily zoophilic but will opportunistically feed on man.

## Medical Importance:

*Anopheles nili* is a vector of *Plasmodium falciparum*.

## WRBU Species Profile



- Adja, A. M., N'goran, E. K., Koudou, B. G., Dia, I., Kengne, P., Fontenille, D., & Chandre, F. (2011). Contribution of Anopheles funestus, An. gambiae and An. nili (Diptera: Culicidae) to the perennial malaria transmission in the southern and western forest areas of Côte d'Ivoire. *Annals of Tropical Medicine & Parasitology*, *105*(1), 13-24.



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# *Anopheles* (*Cellia*) *pharoensis* Theobald, 1901


## Bionomics:

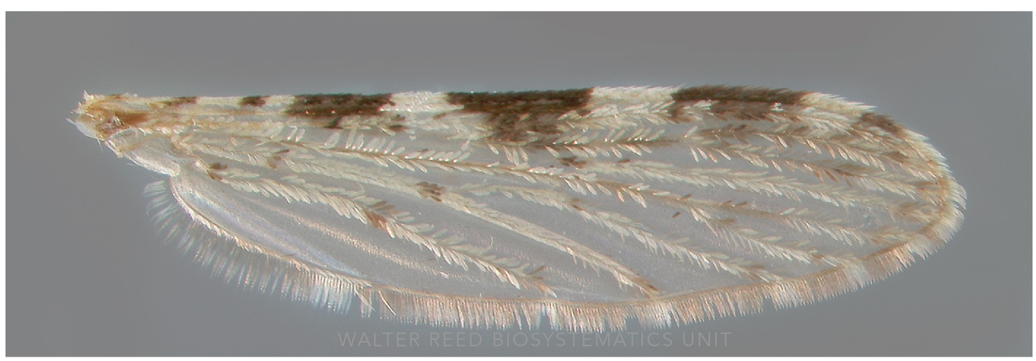
Primarily a species of large vegetated swamps, but is  also found along lake shores and among floating plants, such as *Pistia* and *Potamogeton*. It's also found in reservoirs rice fields, streams, ditches, and overgrown wells. They feed from dusk to dawn with a peak at about 01:00 and will enter homes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

## Medical Importance:

*Anopheles pharoensis* is a vector of *Plasmodium falciparum*.

## [WRBU Species Profile]

- Appawu, M., Owusu-Agyei, S., Dadzie, S., Asoala, V., Anto, F., Koram, K., ... & Fryauff, D. J. (2004). Malaria transmission dynamics at a site in northern Ghana proposed for testing malaria vaccines. *Tropical Medicine & International Health*, *9* (1), 164-170.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# *Anopheles* (*Anopheles*) *paludis* Theobald, 1900

## Bionomics:

*Anopheles paludis* adult females are endophagic but will often elude pyrethrum spray catches as they are exophilic. Although this species is not thought to play a major role in malaria transmission, it has been observed to readily bite humans.

## Medical Importance:

*Anopheles paludis* is considered a secondary vector of *Plasmodium falciparum*.

## WRBU Species Profile

- Bamou, R., Kopya, E., Djamouko-Djonkam, L., Awono-Ambene, P., Tchuinkam, T., Njiokou, F., & Antonio-Nkondjio, C. (2020). Assessment of the anophelinae blood seeking bionomic and pyrethroids resistance of local malaria vectors in the forest region of southern Cameroon. *JEZS*, *8*, 1054-62.
- Tchuinkam, T., Simard, F., Lélé-Defo, E., Téné-Fossog, B., Tateng-Ngouateu, A., Antonio-Nkondjio, C., ... & Awono-Ambéné, H. P. (2010). Bionomics of Anopheline species and malaria transmission dynamics along an altitudinal transect in Western Cameroon. *BMC Infectious Diseases*, *10*(1), 1-12.

# *Anopheles* (*Cellia*) *rufipes* (Gough, 1910)

## Bionomics:

*Anopheles rufipes* females are found both indoors and outdoors in rural and urban environments. It will readily bite humans but will also feed on domesticated livestock such as cows, sheep, pigs, chickens and horses. A recent study in neighboring Cameroon suggests *An*. *rufipes* prefers to enter homes to feed but exit and rest outside after taking a blood meal.

## Medical Importance:

*Anopheles rufipes* is a vector of *Plasmodium falciparum*.

## WRBU Species Profile

- Awono-Ambene, P. H., Etang, J., Antonio-Nkondjio, C., Ndo, C., Eyisap, W. E., Piameu, M. C., ... & Bigoga, J. D. (2018). The bionomics of the malaria vector *Anopheles rufipes* Gough, 1910 and its susceptibility to deltamethrin insecticide in North Cameroon. *Parasites & Vectors*, *11*(1), 1-11.
- Tabue, R. N., Awono-Ambene, P., Etang, J., Atangana, J., Antonio-Nkondjio, C., Toto, J. C., ... & Bigoga, J. D. (2017). Role of *Anopheles* (*Cellia*) *rufipes* (Gough, 1910) and other local anophelines in human malaria transmission in the northern savannah of Cameroon: a cross-sectional survey. *Parasites & Vectors*, *10*(1), 1-11.

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# *Anopheles* (*Cellia*) *wellcomei* Theobald, 1904


## Bionomics:

*Anopheles wellcomei* females will readily enter homes in search of blood meals and prefer to rest indoors. They have been observed in large numbers in West Africa, occasionally outnumbering *An. gambiae* and *An. funestus*.

## Medical Importance:

*Anopheles wellcomei* is considered a secondary vector of *Plasmodium falciparum*.

## WRBU Species Profile


- Krafsur, E. S. (1977). The bionomics and relative prevalence of *Anopheles* species with respect to the transmission of Plasmodium to man in western Ethiopia. *Journal of Medical Entomology*, *14*(2), 180-194.
- White, G. B., Magayuka, S. A., & Boreham, P. F. L. (1972). Comparative studies on sibling species of the Anopheles gambiae Giles complex (Dipt., Culicidae): bionomics and vectorial activity of species A and species B at Segera, Tanzania. *Bulletin of Entomological Research*, *62*(2), 295-317.


# *Anopheles* (*Anopheles*) *ziemanni* Grünberg, 1902

## Bionomics:

*Anopheles ziemanni* is an important local malaria vector across West Africa. Although not found universally across the region, where it occurs it is the dominant species and plays the most significant role in malaria transmission. An aggressive biter, *An. ziemanni* has been observed primarily feeding outdoors (exophagic and endophilic).

## Medical Importance:

*Anopheles ziemanni* is a vector of *Plasmodium falciparum*.

## WRBU Species Profile


- Krafsur, E. S. (1977). The bionomics and relative prevalence of *Anopheles* species with respect to the transmission of *Plasmodium* to man in western Ethiopia. *Journal of Medical Entomology*, *14*(2), 180-194.
- Tabue, R. N., Nem, T., Atangana, J., Bigoga, J. D., Patchoke, S., Tchouine, F., ... & Fondjo, E. (2014). *Anopheles ziemanni* a locally important malaria vector in Ndop health district, north west region of Cameroon. *Parasites & Vectors*, *7*(1), 1-11.


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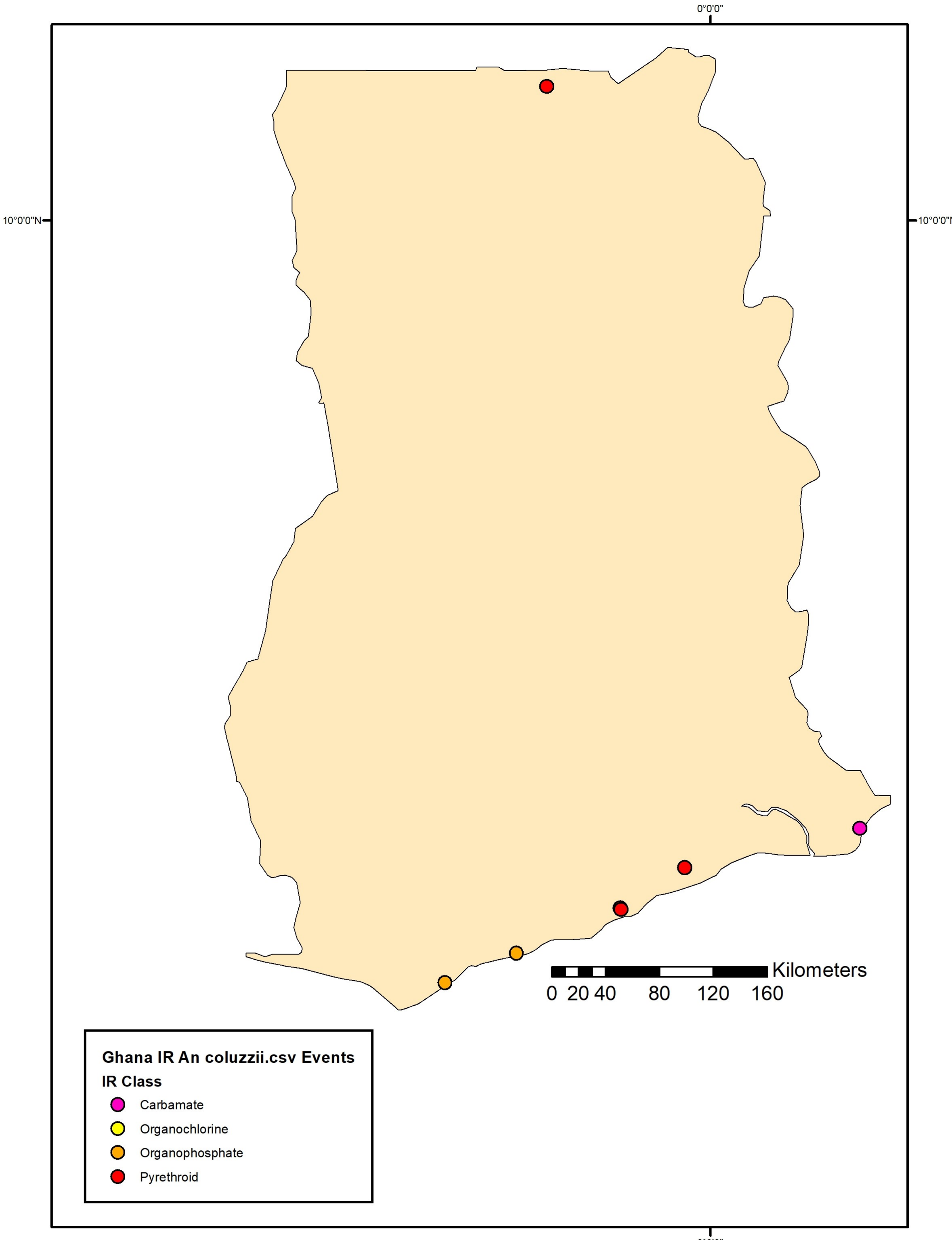
# Insecticide Resistance Detected: *Anopheles coluzzii*

Data Sources:
VM all *An. coluzzii* s.l.
IR Mapper (*Anopheles coluzzii*)
VectorBase (*Anopheles coluzzii*)

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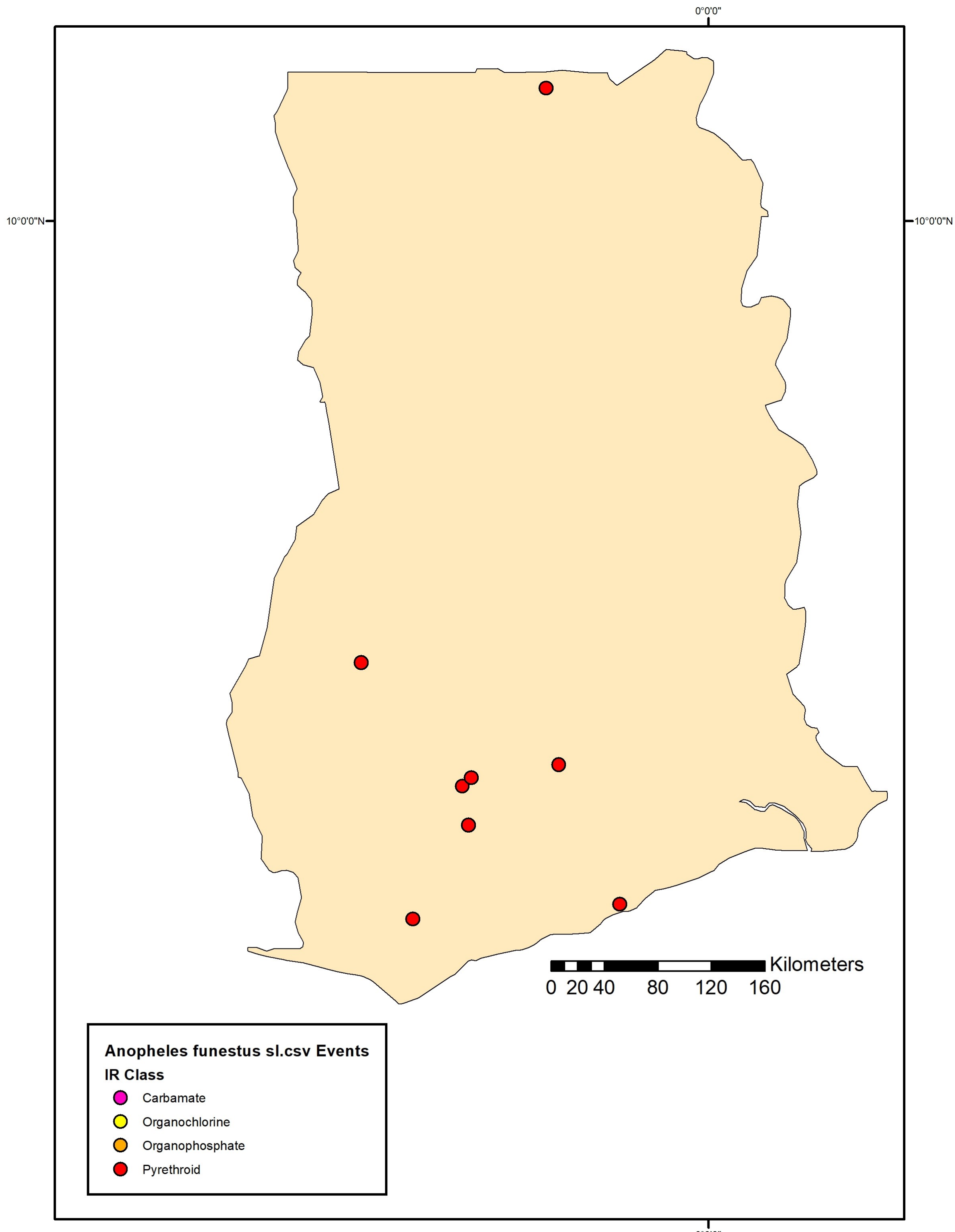
# Insecticide Resistance Detected: *Anopheles funestus*

Data Sources:
VM (*Anopheles funestus* + Ghana)
IR Mapper (*Anopheles funestus*)
VectorBase (*Anopheles funestus*)

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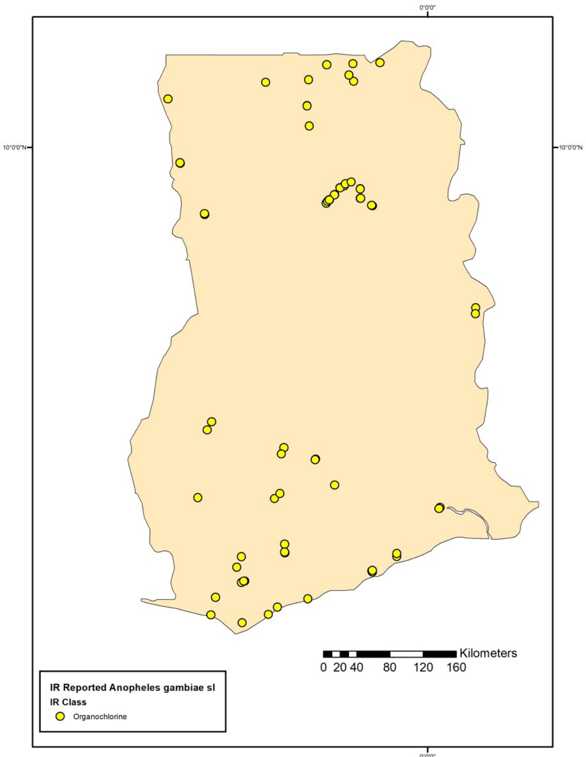
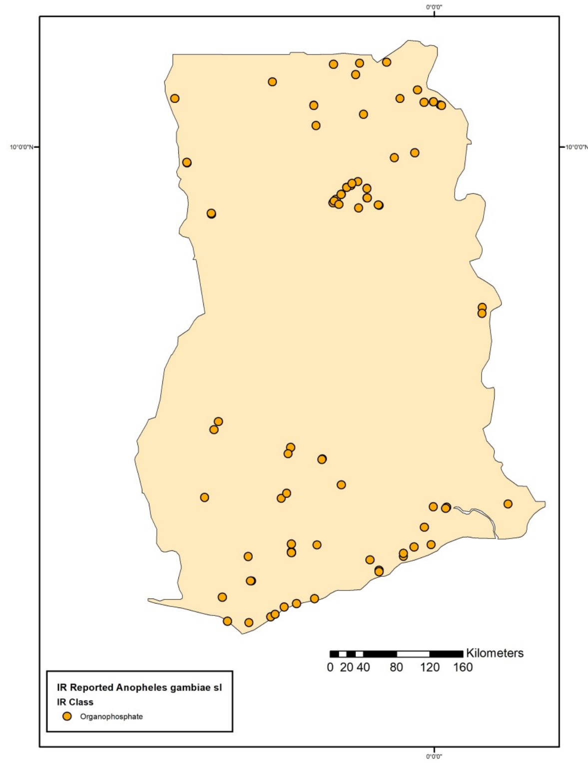
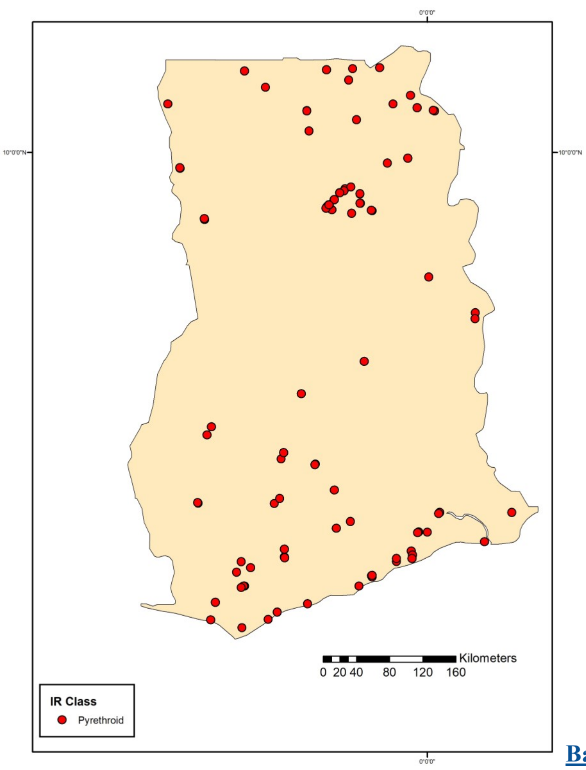
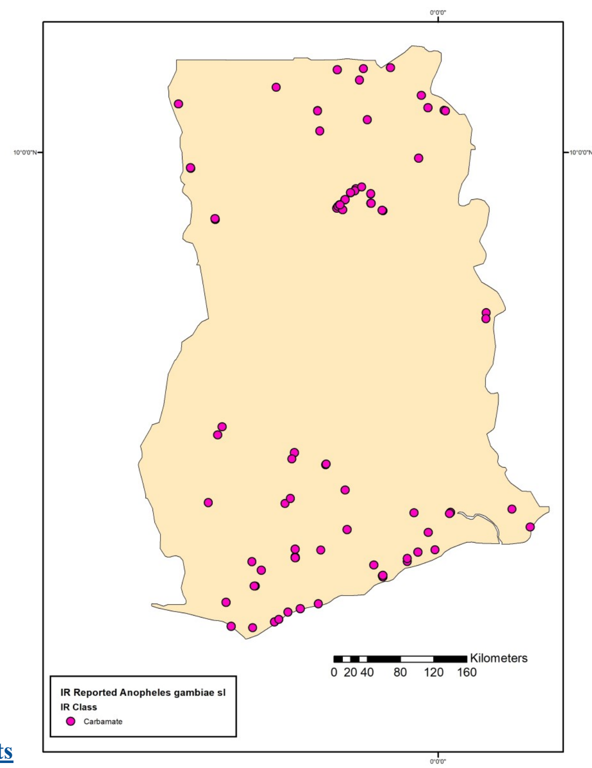
# Insecticide Resistance Detected: *Anopheles gambiae* s.l.

Data Sources:
VM all *An. gambiae* s.l.
IR Mapper (*Anopheles gambiae*)
VectorBase (*Anopheles gambiae*)

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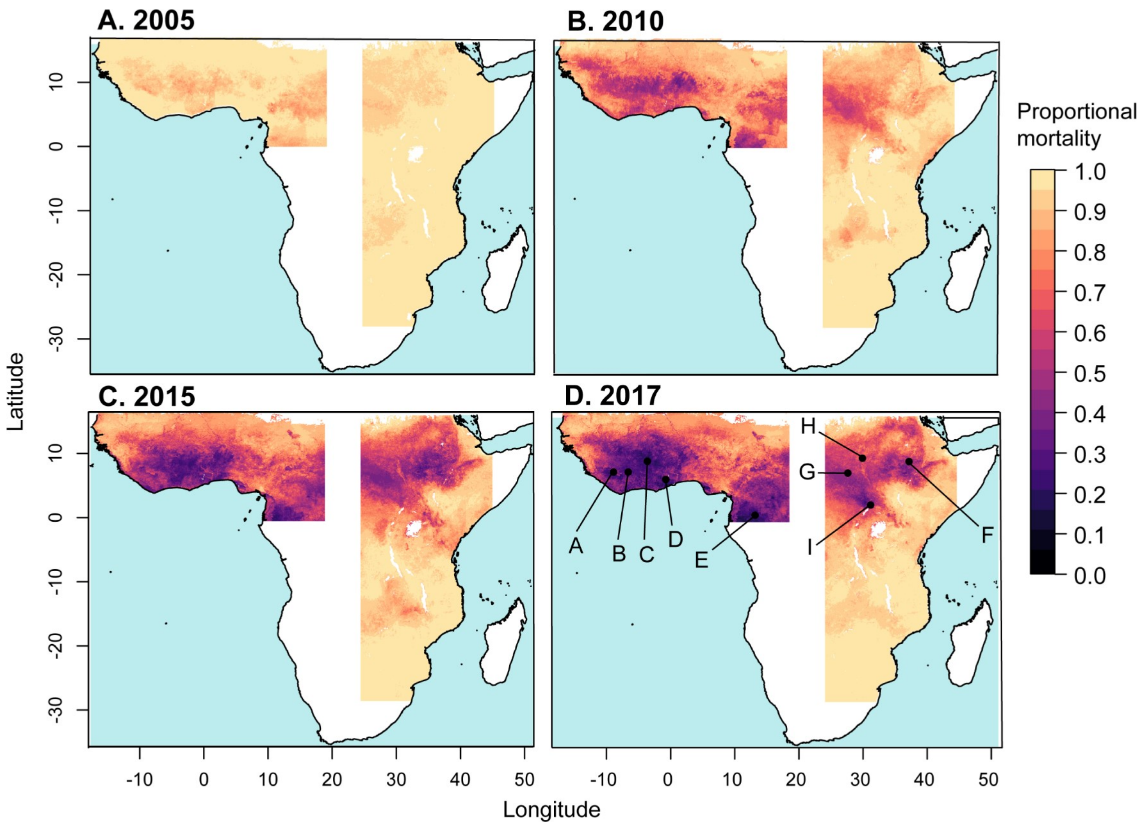
# Spotlight: Increased Insecticide Resistance

## Significant Increase in Deltamethrin Resistance Detected in West Africa (2005-2017)




**Predicted mean proportional mortality to deltamethrin across the west and east regions (2005-2017)** Full access at [10.6084/m9.figshare.9912623](10.6084/m9.figshare.9912623)

A recent study investigated insecticide resistance screening results from mosquitoes collected across West Africa from 2005 to 2017 in order to predict the change in prevalence overtime. A key finding was that resistance to all pyrethroids dramatically increased. For deltamethrin specifically, it was observed that in 2005 resistance was thought to occur across only 15% of the region and increased to 98% by 2017. Resistance rates appear to be highest in Liberia, Cote d'Ivorie and Ghana.

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- Hancock, P. A., Hendriks, C. J., Tangena, J. A., Gibson, H., Hemingway, J., Coleman, M., ... & Moyes, C. L. (2020). Mapping trends in insecticide resistance phenotypes in African malaria vectors. *PLoS biology*, *18*(6), e3000633.
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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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**Additional Resources:**

- # 1 Cause of Death in Ghana is Malaria
- CDC Travelers Health
- WHO Global Health Observatory:
- WHO Map Gallery
- CIA FactBook


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