The predators of *Anopheles gambiae s.l.*

What are the interacting predators of Anopheles gambiae s.l. in local ecosystems?

The *Anopheles gambiae sensu lato* (s.l.) complex currently has eight recognised species. The ability to transmit malaria parasites to humans varies greatly among these, but ***An. gambiae, An. coluzzii*** **and** ***An. arabiensis*** **are considered the primary malaria vectors in Africa.**

Mosquitoes interact with many different organisms: they are eaten, parasitized and infected by natural enemies. This factsheet summarises a wide review of published literature that considers *An. gambiae* s.l. mosquitoes as a food resource to predators.

Predators

Predators are ''specialist'' or ''generalist'' based on whether their natural diets are ''narrow'' or ''broad'' and the many studies available provide an overview of the predators of *Anopheles gambiae s.l.* Juvenile mosquito life stages are restricted to the water bodies in which they hatched and, especially in small water bodies, can be concentrated at high densities. Adults are mostly spread out, harder for predators to locate and catch relative to larvae and are of low food value compared to flying prey such as Lepidoptera (butterflies and moths).

Predation of larvae

There are many natural enemies of mosquito larvae, including insects, spiders, hydras, planaria, copepods, bats, bird and fish (see tables). In some aquatic environments, predators may account for most natural mortality of immature stages of mosquitoes, but the egg-laying choices of female *An. gambiae* affect predator encounter rates substantially. Females avoid water containing predators and too many competing larvae. They do lay in a great variety of water bodies; the most important are small, shallow, sunlit and usually temporary pools. Because of this, few predator species successfully colonise them and environmental effects, such as evaporation, flushing and reduced food sources may be stronger effects than predation.

Only generalist predators are recorded as being consumers of *An. gambiae s.l.* larvae. No study found suggests a dependence or specialism by any larval predator.

Predation of adults

Adult anopheline mosquitoes are a small part of the insect biomass fed on by insectivores across Africa. Males are typically smaller than females and there is a potential biomass of 50-235 g/km2 in the wet season and one tenth of that in the dry. These small, mobile insects of low profitability (energy gained over hunting and handling time) are unlikely to be a food source that optimises fitness and energy intake for predators. Although many different animals do eat mosquitoes, the majority of these predators are generalist and consume mosquitoes only in addition to other small, aerial invertebrates.

Anopheles gambiae s.l. prefers to obtain blood meals from humans than other animals. Females typically feed late at night on humans as they sleep indoors. This is an opportunity for predators as mosquitoes, mostly female, though males also, can be aggregated in houses when resting after a blood meal. Another opportunity for predation of adults is in swarming aggregations where males come together to seek mates.

A single species of jumping spider is recorded as predating preferentially on female mosquitoes when they are resting in houses to digest their blood meal. Female mosquitoes (of various species) make-up about 63% of *Evarcha culicivora*'s diet. This predatory spider with a relatively narrow diet range also eats other insects and has a restricted distribution in East Africa near the shores of Lake Victoria.

Summary

Anopheles gambiae s.l. is a significant species because of its role as a vector of malaria, not as a key component of ecosystem food webs. Adult *An. gambiae s.l.* mosquitoes are a relatively low-value, low-volume and disaggregated resource and there is a lack of evidence for any tightly-linked predators. No predators are recorded as being closely associated or dependent on larvae of these mosquitoes. The high seasonality of *An. gambiae* throughout most of its range and the ephemeral nature of many of its larval habitats also limits predation to generalist species that may take it as prey when opportunity occurs.

Table 1: Summary of evidence of invertebrate predator interactions with larval and adult *Anopheles gambiae* s.l.

Predator Group	Larval	Adult
Flies (Diptera)	Many species of generalist predatory dipteran larvae are recorded in aquatic habitats. There is no evidence of specialism on *An. gambiae s.l.* in any.	Shore flies (*Ephydridae*) are seen predating adult mosquitoes, but these curious flies do not specialize on *An. gambiae s.l.*; they are opportunistic generalist predators.
True Bugs (Hemiptera)	No hemipteran predators specialize on An. gambiae s.l.; they are broad, generalist predators. There is some evidence that female mosquitoes will avoid oviposition in water that contains hemipteran predators.	No evidence of interaction.

Predator Group	Larval	Adult
Dragonflies and Damselflies (Odonata)	Odonata are sometimes considered to be voracious predators of mosquito larvae. This is not supported by the available literature. The odonate larvae are true generalist predators, with wide range of dietary choice.	Several species of Odonata are predators of adult mosquitoes and have been seen to feed opportunistically on male swarm aggregations, but there is no evidence indicating that they are specialist predators of *Anopheles gambiae s.l.*
Shrimps and others (Crustacea)	Crustacean predators are widely present in more established water bodies. With a broad diet, these are generalist predators. Their presence can also deter mosquito oviposition.	Predation not present outside the aquatic environment.
Spiders (Arachnida)	Many of the studies identified do provide some basic information on predation by aquatic or peri-aquatic hunting spiders, but there is no evidence of diet specialisation on mosquito larvae and these are considered generalist predators.	A single species of jumping spider (Salticidae) is known to predate preferentially on blood-fed female mosquitoes when they are resting to digest their blood meal. Female mosquitoes make up c63% of *Evarcha culicivora*'s diet. This predatory spider with a relatively narrow diet range has a restricted distribution in East Africa near the shores of Lake Victoria.
Flatworms (Planaria)	Although some planarians will readily consume mosquito larvae, these are generalist predators.	Predation not present outside the aquatic environment.

Table 2: Summary of evidence for vertebrate predator and parasitic species interactions with larval and adult *Anopheles gambiae* s.l.

Vertebrate Predators	Larval	Adult
Bats (Mammalia, Primata)	Predation not present in the aquatic environment.	The few detailed studies of bat diet available indicate clearly that mosquitoes form a very small proportion of their diet.

Vertebrate Predators	Larval	Adult
Birds (Aves)	Many birds making-use of freshwater habitats are insectivorous and thus likely to feed on mosquito larvae as part of an opportunistic broader diet. There is little quantitative evidence of specific mosquito consumption in the aquatic larval habitat.	Insectivorous birds are generalist predators, *Anopheles gambiae s.l.* mosquitoes are not a significant portion of their diet.
Fish (Osteichthyes)	Insectivorous bony fish are naturally present in many stable long-term aquatic habitats. Mosquito larval density varies with fish presence, but fish presence has not been shown to vary with *Anopheles* larval presence. Insectivorous fish have a diverse diet and even those proposed as biological control agents of mosquitoes are not specialists of *Anopheles gambiae s.l.*	Predation not present outside the aquatic environment.
Parasitic species in aquatic habitats	There are likely numerous parasites of mosquitoes; the most documented are fungi and nematodes. Although evidence points to high infection rates in many natural habitats, no evidence suggests any specialisation on *An. gambiae s.l.*	

Selected references:

Collins et al. (2018), Effects of removal or reduced density of the malaria mosquito, *Anopheles gambiae s.l.*, on interacting predators and competitors in local ecosystems, *Medical and Veterinary Entomology*

Kweka, E. J. et al. (2011) 'Predation efficiency of *Anopheles gambiae* larvae by aquatic predators in western Kenya highlands', *Parasites & Vectors*