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From prey to pollinator: Unmasking the diverse ecological roles of mosquitoes (Diptera: Culicidae)

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Abstract
Mosquitoes are a component of a successful biosphere that has evolved on the planet for at least 100 million years. This review aims to investigate mosquito's ecosystem services and their value in various environments. According to popular belief, mosquitoes must be eradicated from the entire planet because they are culpable for the enormous suffering of mankind and wildlife beings resulting in significant morbidity and mortality and obstructing cultural and financial growth. But out of more than 3500 species, only a few hundred are considered pests, and the rest do not even exist in areas where humans live because they choose to feed on some other animals. Along with all the unpleasant aspects, mosquitoes have also many beneficial impacts on the world around them. Mosquito larvae and full-grown adults replenish nutrition for a variety of species, assist in pollination, serve as environmental filters, and are used in biological control. Before considering and supporting a mosquito eradication policy, which could result in a paradigm shift in the environment, the significance of mosquitoes must be assessed from a wider ecological and evolutionary viewpoint.

Keywords: Mosquito, insect, pollinator, food, environment

Introduction

The world was inhabited by mosquitoes even before man. The earliest mosquito fossils were noticed date back to the cretaceous period, around 200 million years ago [1]. A 79 million years old mosquito, *Paleoculicis minutus*, with modern-day anatomy, was discovered in Cretaceous amber in Canada [2]. *Burmaculex antiquus* was discovered in Burmese amber approximately 99 million years old, another older species with even more basic traits [3]. *Priscoculex burmanicus*, a species of a similar age as *Burmaculex* sp., was recently recorded from Myanmar amber, but it was identified as relating member to the modern subfamily Anophelinae, implying that the split between the two subfamilies may have occurred before this time [2].

Mosquitoes were already found in a diverse range of terrestrial and aquatic environments from temperate to tropical locations around the world. They refer to the Diptera order's Culicidae family. It has 3584 species divided into two subfamilies: Anophelinae and Culicinae, as well as 113 genera with morphological and behavioral adaptations to a variety of habitats and ecosystems [4]. Male and female mosquitoes typically feed on nectar, aphid honeydew, plant juices, and fruits for energy and nutrition in the form of sugars, but females in many species suck blood as ectoparasite to acquire proteins for egg development [1].

The most popular group of insects, mosquitoes serve as carriers for some of the world's most dangerous diseases. Among all species, there are approximate 100 mosquito vector species that transmit malaria, filariasis, yellow fever, zika fever, dengue fever, Japanese encephalitis, rift valley fever, chikungunya virus, and West Nile virus by putting enormous health and economical pressure on people [5, 6]. Significant mosquito vectors can be categorized into anophelines (*Anopheles*) and culicines (*Aedes*, *Culex*, *Mansonia*, *Sabethes*, and *Haemagogus*). An estimated 100 to 400 million dengue virus infections each year and 229 malaria infections were reported worldwide in 2019 according to the World malaria report [7, 8].

A widely accepted belief in culture is that mosquitoes are intended to annoy, spread disease, pain, mortality, and therefore they must be eradicated from the world. Now the question is quietly being raised: what would happen if mosquitoes were fully eradicated? Each creature is the product of natural selection and plays an ecological role in the natural world, including mosquitoes. Even though mosquitoes have been fought for over a century with improvised weapons, they have survived and thrived. In today's world, mosquito-borne diseases are almost universal. It can be perceived as an assurance that mosquitoes have lived as the fittest by natural selection and even with concerted human efforts to eradicate them. As a result, the objective of this review is to look into mosquito's ecological functions and their significance in various ecosystems.

Ecological significance

Assessing the worth of animals is challenging and will often be incomplete but every species is an essential part of the ecosystem, and the benefit they deliver in the form of resources should be included in all ecosystem evaluations. Mosquito eradication could put an end to evolution. Loss of biodiversity or species collapse may destroy environmental functions resulting in cascading and devastating co-extinctions [10-12]. As a result, extensive research is required within this scenario in analysis to define the mosquito's potential ecological function, which has previously been unspecified.

Impact on migratory animals

For a long time, mosquito crowds especially *Aedes nigripes* and *Aedes impiger* species have plagued caribou at the Arctic tundra. When the process of snowmelt begins, the insects' eggs hatch the following year, and growth to the adult stage takes just 3–4 weeks [13, 14].

They are extremely prevalent from northern Canada to Russia for a short time, creating dense clouds in some regions. According to Daniel Strickman, "That's an exceptionally rare situation worldwide." That is the only place on the planet where these creatures are abundant as this biomass [13]. At Arctic climate modification (rises temperature) is influencing mosquito groups as they mature quicker, develop faster, and last longer [5]. Mosquitoes also affect caribou migration paths. Mosquitoes can devour approximately 300 milliliter blood each day from almost every animal of the caribou herd, which is considered to evade the swarm by preferring routes that confront the storm [13]. Large numbers of caribou travel via the Arctic impinging the field, consuming lichens, exporting nutrients that have an influence on vegetation dispersion, wolf foraging patterns, and so forth [13, 14]. Bruce Harrison thinks that the population of migrating birds that nest on the tundra might plummet by greater than half in absence of mosquitoes to feed. If mosquitoes are eradicated, the enormous animals' traveling routes may be disrupted, causing serious repercussions in the environment of the Arctic region [13].

As an effective pollinator

Several hundred nectar-feeding mosquitoes were reported in the surroundings of certain plants. One part of mosquito sensory behaviour that has gained relatively less attention is nectar feeding. For both male and female mosquitoes, nectar and sugar feeding are essential for increasing their longevity, life expectancy, and fertility, and for males, it is necessary for existence [14]. Mosquitoes spend most of their time adjacent to aquatic or near-aquatic plants so play a beneficial role in pollination and continue the existence of these plants, which provide protection and shelter for other animals and species [15]. Mosquitoes were discovered to be pollinators for the first time in 1913. While the most of mosquito–plant encounters indicate that mosquitoes provide little in the way of reproductive services to the plant.

Scientists discovered that the *Aedes communis*, also known as the snow pool mosquito, was a significant pollinator of the blunt-leaf orchid *Platanthera obtusata* in the early 1970s [16]. This snow pool mosquito consumes nectar from the floral spur, causing its eye to get in touch with the pollinium, a mass of pollen. Even though the mosquito takes flight, the pollinium remains attached to its eye. Whenever it feeds from some other bloom, the pollinium comes into contact with the stigma of that bloom, pollinating it. The mosquito flower, *Lopeziara cemosa*, is pollinated by *Culex pipiens*. Pollination of the *Silene otites*, Spanish catchfly, is supported by *Culiseta annulata*, *Culex pipiens*, and some nocturnal lepidopterans. Small northern bog orchid *Platanthera* (*Pl.*) *obtusata*, the pale green orchid *Pl. flava*, *Pl. hyperborean* (the Northern green orchid), and probably *Pl. stricta* (the slender bog orchid) and *Dryas integrifolia* (white mountain-avens) pollinated by *Aedes* spp. Mosquitoes carry pollen from *Symplocarpus renifolius*, Asian skunk cabbage, and also pollinate cacao plants [17]. In addition to potter wasps, *Culex tarsalis and Culiseta incidens* assist in the pollination of *Solidago canadensis* (Canada goldenrod). Pollination of the green labellum orchid *Pterostylis procera* by *Aedes* sp., *Anopheles annulipes*, and probably *Culex* sp., some of them also pollinate *Pt. falcata* (the nodding greenhood orchid) and the *Pt. acuminata*, the pointed greenhood orchid. Pollination of *Tanacetum vulgare* by *Culex pipiens* has been confirmed, as has possible pollination of other Asteraceae, including *Achillea millefolium*, by a variety of mosquito species. *Burmannia lutescens*, *Gnetumcuspidatum*, and *Sciaphilasecundi flora* were found to be pollinated only by *Culex* spp. and Armigeres spp. *Habenaria obtusata*, an orchid genus, is widely distributed in Alaska, Norway, Siberia, Canada, and other parts of the world, and is pollinated by *Aedes* mosquitoes that noticed in glass cabinets [18]. Mosquitoes are also thought to be unintentional pollinators of several Umbelliferae plants. Almost every insect that walks over them in search of nectar can pollinate these plants. Anise, dill, carrots, caraway, celery, cumin, coriander, and parsnips are among the garden form family plants thought to be pollinated by mosquitoes. The umbrella-shaped blossoms are a good source of food for a vast range of insects [19]. During the limited blossoming period in the Arctic, plants rely on massive swarms of nectar-hungry mosquitoes to pollinate them [16, 20]. While mosquitoes are not regarded as key pollinators, they do perform a considerable role in pollination in the subarctic regions of Northern Canada and Russia [21, 22].

Role in honeydew accessing

Aphids and other plant-sucking pests emit honeydew (a sugary waste substance) and mosquitoes use it as a food source and that is a lesser ecologically significant role than pollination [20]. In a study female of the malaria vector, *Anopheles gambiae* who were fed honeydew from the mealybug *Pseudococcus longispinus* survived significantly more than individuals who were only fed water [23]. Numerous ants also raise aphids to harvest and feed honeydew. With a few strokes of its antennae, an ant can get a fellow ant that has previously ingested honeydew to regurgitate and exchange some of their food. Some mosquito fools an ant into regurgitating and sharing its honeydew by inserting its mouthparts inside the ant's mouth and stroking the ant's head with its antennae. However, honeydew is difficult to come by in the wild but mosquitoes have found a solution to this difficulty by detecting the odors released by bacteria living in honeydew [20].

Work as environmental filter & compost maker

Mosquito larvae contribute a significant amount of biomass to water habitats around the world. They can be found in a variety of water bodies, including temporary ponds, tree holes, and damaged tires and the frequency of larvae on waterlogged fields can be quite great that their writhing creates waves across the surface. They eat rotting leaves, organic waste, and microbes, algae, fungus among other things for food [24, 25]. Mosquito larvae nourish upon debris which hovers and plugs the water's surface preventing the material from suffocating plants below with nitrogen and oxygen. Without mosquitoes to eat the trash, the plants and ecosystems they sustain may perish, as they won't be able to acquire the nutrients they need to survive.

Mosquito larvae are crucial representatives of the close-knit populations occurring within *Sarracenia purpurea* (pitcher plant) on the east coast of North America. The only insects that reside there are mosquitoes (*Wyeomyia smithii*) and midges (*Metriocnemus knabi*), as well as microorganisms like rotifers, bacteria, and protozoa. Midges scoop up the carcasses of other insects that sink in the water, while

mosquito larvae nourish on the residual material providing nutrients like nitrogen obtainable to the vegetation [11, 12]. Frass (insect poop) is a product of mosquito larvae. Millions of mosquito larvae consume detritus that dumped in and out into the water. Insect feces are incredibly nutritious for plants, and when it is ejected, all of the nutrients are promptly dissolved in water. Frass works as a bloom stimulator and a source of important nutrients for plant growth and health [24]. Mosquitoes constitute a vital part of a sustainable water ecosystem because they filter detritus and aqueous bacteria, and once individuals emerge, mosquitoes establish a connection across terrestrial and aquatic ecosystems. Within that scenario, removing mosquitoes may have an impact on vegetation proliferation.

Tropical rainforest protector

Mosquito breeding sites are typically the last locations we humans want to live, work, or spend our vacations. Our nefarious 'friend' has rendered vast swaths of the tropical rainforest unusable. This indicates that one of the minute organisms on the planet is safeguarding the rainforest's crucial biodiversity. Mosquitoes aren't merely a nuisance to humans and animals; they defend natural ecosystems, as well as plants and trees [24].

As a biological control agent-

Mosquito genus larvae which feed upon the larvae of distinct container-breeding mosquitoes (carriers of public health concern) and can include their species are among the greater intriguing invertebrate predator-prey interactions in the aquatic ecosystem. *Toxorhynchites, Armigeres, Megarhinus, Eretmapodites, Lutzia,* and *Psorophora* are among the mosquito species found for biological control but *Toxorhynchites (T.)* is the well-studied of them. It's also recognized as the "elephant mosquito" or "mosquito eater," and it's a non-biting, global mosquito genus that deposits its eggs in water containers and tree holes. Because there is no demand for a blood meal at the adult stage they cannot operate as disease vectors and are believed safe to humans. The adults consume sweetener foods including honeydew, fruit, and nectar, while the larvae eat other mosquito larvae and other nektonic (free-swimming) creatures. *Toxorhynchites* have gathered the required resources for oogenesis and vitellogenesis because they eat a protein- and fat-rich meal of aquatic animals like larvae. *Toxorhynchites* larvae feed on some other mosquito larvae and engage in "pre-pupal slaughter." Because adults are relatively larger than the larvae of *Aedes*, they are frequently used as biological control agents for *Aedes aegypti* and other *Aedes* mosquitoes [26, 27]. According to a little-known fact, some *Anopheles* larvae are predaceous on specified insect larvae, including mosquito larvae. *Culicoides* larvae and young instars of distinct tree hole mosquito larvae are efficiently consumed by *Anopheles barberi* [26].

Act as prey or predator (Role in the food web)

Mosquitoes have lived on the globe for almost 100 million years and have evolved into a critical component of the food chain. At Michigan State University in East Lansing, an aquatic entomologist Richard Merritt tells "Mosquitoes are delicious to feed and convenient to grab [12].

Mosquito larvae are aqueous organisms that perform a critical part in the aquatic environment and appear to be a significant source of nutrition for animals at the bottom of the food chain. In "The Handy Bug Answer Book" by Dr. Gilbert Waldbauer mosquito larvae are filter consumers that extract minute organic components including unicellular algae from the water and transform these to the tissues of their respective bodies, which are then devoured by fish [1].

Migratory birds rely on these insects as a supply of nutrition. For instance, in the Arctic tundra, multiple mosquito populations thrive and offer nourishment for migratory birds. The abundance of birds in the region may drop by 50% if mosquitoes were eradicated. Fish and other aquatic creatures eat mosquito larvae because they are nutrient-dense appetizers. In contrast, if mosquitoes were extinct, so would other insects and fish that rely on them, potentially causing a domino influence across the food chain. Specialist predators like *Gambusia affinis* (mosquito fish), a specific feeder which is placed in paddy fields and swimming pools as pest management because it is so good at killing mosquitoes, possibly will become extinct. Several fish populations all over the world, according to some scientists, may experience a comparable destiny and will have to modify their eating habits to succeed. "This may sound simple, but traits such as feeding behavior are deeply imprinted, genetically, in those fish," says Harrison. Like a predator, they devour aphids, which are plant invaders [12].

Of course, their involvement at the base of the food chain does not cease with the larval stage. Adult mosquitoes that persist quite longer on the water surface while depositing their eggs is frequently eaten by fish, as are larval mosquitoes. Birds, spiders, and bats, as well as fish, tadpoles, frogs, turtles, salamanders, dragonflies, lizards, songbirds, waterfowl, swallows, ingest mosquitoes as adults [10, 28, 29]. *Delichonurbica* (common house martin), *Ficedula hypoleuca* (European pied flycatcher), *Hirundorustica* (swallows), *Anthuspratensis* (themeadow pipit), and *Apus apus* (common swift) are the mosquito-eating species of birds [30]. Mosquitoes play an essential role in the diet of the little forest bat (*Vespa delusvulturnus*). *Evarchaculicivora* and *Paracyrbawanlessi*, two jumping spiders, have a love for mosquitoes. The *Evarchaculicivora*, also known as the vampire spider, feeds on female *Anopheles* mosquitoes that have just had a blood meal in East Africa. In Malaysia, *Paracyrbawanlessi* (which looks like a small cat) attacks both larval and adult stages of mosquitoes. An ant species called *Camponotus schmitzi* dwells within the stems of the *Nepenthes bicalcarata* (pitcher plant). These ants can move underneath the surface of the pitcher plant's water to consume mosquitoes and their larvae [31].

Mosquito hawks (crane flies/leatherjackets/daddy longlegs/gollywhoppers) love to devour mosquitoes. They can be found throughout the world, although they are most frequent in the tropics, where they thrive. Bluebirds, purple martins, and cardinals also eat mosquitoes. Damselflies are predatory insects that feed on other insects, and they are known to congregate around mosquito breeding areas such as bogs, swamps, rivers, and ponds. They rely on mosquitoes as their principal source of nutrition [32].

Numerous copepod species have been identified as efficient feeders of mosquito juvenile instars, including *Cyclops vernalis, Mesocyclops (M.) aspericornis, M. formosanus, M. guangxiensis, M. edax, M. thermocyclopoides,* and *M. longisetus*. *Polypedatescruciger* tadpoles feed on the eggs of *Aedes aegypti* as well as those from the *Bufo, Ramanella,*

Euphlyctis, and *Hoplobatrachus* genera [27]. Adult mosquitoes which die (or are ingested and expelled) disintegrate, converting the microorganisms they ate as larvae into plant nutrients [20].

Hundreds of fish types would have to adapt their nutrition to thrive if their larvae were not present. However, because these organisms aren't fully reliant on mosquitoes, it's expected that if mosquitoes are eliminated, they'll relocate to other insects that will be accessible in greater quantities [13]. In a study, after spraying the region with a microbial agent for mosquito-control, researchers followed insect feeder house martins in a garden in Camargue, France. They discovered that after spraying, the birds produced two chicks per nest on average, contrary to three at control sites [12]. Hydra is a general mosquito larvae predator, and their fast frequency of reproduction asexually enables them unconventional mosquito biological control options. Other mosquitoes that act as predators and prey of different organisms are listed in Table 1 [26].

Species diversity enhancer

Mosquitoes are important in the environment and have vast diversity. In 1974, Canadian biologist John Addicott noticed that mosquito larvae had increased protozoan diversity. Addicott felt that when larvae ingest, the frequency of influential protozoa species decreases, allowing for more diversification [5]. Chickadees, swallows, house wrens, warblers, sparrows, grey catbirds, bluebirds, vireos, tanagers, and orioles, all grab airborne insects when they are active in the air, allowing the birds to ingest the insects avoiding perching, and subsequently turning into prey to predators, enabling the existence of various bird species. Generally, mosquitoes are not the primary source of food for birds but they can influence the development of a subsequent population of birds (ensuring the species' survival) by occasionally nourish their babies on them. Birds aren't the only ones who have a relation between mosquitoes and species diversification. Pollination through mosquito is also imperative for the continued existence of a variety of plant species. A sustainable environment advantages from a diverse variety of flora and fauna [15].

Economic industry developer

Mosquitoes have a significant impact on the worldwide economy. It is easy to find their influence by considering accessible bite cure options and numerous repellents. The several types of repellents developed to remain those horrible insects away from humans are a multi-billion dollar industry all over the world. As a result, they contribute to the worldwide GDP by establishing a separate industry [24].

Engineer's guide

Mosquitoes are causing havoc in the engineering sector. Recently, engineers designated filming equipment that can significantly delay mosquito flying to observe every single action of a mosquito's wing. To create mosquito-like drones, engineers are now studying the interaction of mosquito wing speed, wing mobility, and leg motion. This will not disrupt the environment during takeoff or landing of drones [24].

In medical research

Although mosquitoes are well-known for transmitting disease worldwide, scientists are looking into mosquitoes as potential medical therapies. The possibility of using mosquito saliva to treat cardiovascular disease, the world's top cause of mortality in humans, is high. According to scientists, the saliva may comprise qualities that could contribute to the formation of anti-clotting medications including certain capillary dilators and clotting inhibitors. Mosquito saliva has a comparatively basic structure, with less than 20 major proteins in most cases. Following significant progress in understanding these compounds and their involvement in blood meal, researchers still just know around 50% of the substances existing in the saliva of the insect [1]. Whenever mosquitoes attack humans, people frequently do not experience the bite just because the insect's mouth effectively anesthetizes individuals. A few of mosquito saliva's anesthetic characteristics have been explored and synthesized into topical and regional anesthetics that doctors employ to desensitize a patient receiving medical treatment. According to "Mosquito Info," A prototype device has been designed to permit diabetic patients to monitor individual's blood sugar quite gently using a gadget that looks like a mosquito's mouth tentacles [15]. Even the prospect of turning insects into living vaccines is being investigated [24].

Population controller

In nature, overcrowding typically contributes to famine and death, and as a solution mosquitoes have a crucial purpose in nature, which is why people despise them so much. Mosquitoes were already decimating the population of animals for long periods and quite lately, humans. They have ferocious dietary habits and constructed hypodermic needles, which make them efficient pathogen carriers. Several infections would decrease or halt if mosquitoes were not there, and animal populations would boost as a result [33].

As a food during travel

Mosquitoes provide a food supply for birds and animals during migration in other hostile environments. They are a dependable fast-food alternative in the wilderness of Alaskan (desolate environment) where food sources are scarce. In the summer season, when birds migrating from south side to north side, they rely on the massive amounts of mosquitoes those swarm in some location to stay fueled and move. The migration journey does not seem to be feasible without them, and the proportion of birds that stay alive along the route may drop considerably [33].

Table 1: Role of mosquitoes as either prey or predator for class insecta members

Order of predator	Predator	Prey
Coleoptera	*Tropistemus lateralis*	*Culex peus*
	Agabus erichsoni	*Aedes stimulans, Aedes trichurus*
	Laccophilus maculosus, Agabus anthracinus and Ilybius biguttulus	*Aedes atropalpus*
	Laccophilus maculosus and Laccophilus fasciatus	*Culex pipiens*
Hemiptera	*Notonecta unifasciata*	*Aedes aegypti*
	Callicorixa audeni and	*Aedes* larvae

	Callicorixa alaskaenis	
	Belostoma flumineum and *Abedusindentatus*	Mosquito larvae
	Ptychadena	*Aedes vittatus*
Odonata	Dragonfly naiads	*Aedes vittatus*
Diptera	*Anopheles barberi*	*Culicoides larvae*
	Culicoidesca vaticus	*Aedes sierrensis*
	Forcipomyia, Culicoides guttipennis	*Aedes aegypti*
	Chaoborus crystallinus	Woodland mosquito
	Mochlonyx culiciformis	*Aedes communis*
	Dolichopusgratus	Mosquito larvae
	Tachydromia	*Anopheles*
	Toxorhynchites	*Aedes* larvae

Discussion

Mosquitoes have a significant influence on the planet "Mosquitoes have been on Earth for almost 100 million years, and they have co-evolved with so many species along the way," Murphy says [12]. The relationship between mosquitoes and the environment is quite incredible. The mosquito, while annoying and even deadly to people, performs an important function in maintaining the stability of life. They have an impact on all species, even humans, and are a plentiful and frequently inexpensive food supply for insectivorous. Apart from mosquitoes, there would be no prey for predators and no pollinators for some plants. Mosquitoes nourish a wide range of fish insects, reptiles, and birds, and they effectively transport pollen between plants by eating on nectar. It is estimated that if mosquitoes were not present, the population of birds would reduce by half. Richard Merritt, an aquatic entomologist, cautions that some fish may go lost. The food chain would be affected in both respects if these fish were not present [34]. Some spiders, salamanders, lizards, frogs, and other insect species could be greatly diminished. It may not feel like eliminating some of the mosquito's biological predators is a huge concern, but those creatures' predators might contain some of our basic food supplies. Areas of the environment would perish without them, permanently disrupting nature's food chain. It's fair to assume that if the mosquito disappeared, sections of our ecosystem would suffer one by one. Certain plants that depend on mosquito pollination may perish as a result. And the greater plants we remove, the lower the oxygen levels on the planet become. This has an impact on the amount of oxygen available to humans, other mammals, and other organisms. They're also a driving force in defense mechanism evolution. Because thus many mosquito species do not transmit diseases, they are relatively innocuous organisms with a minor impact on the environment. Mosquito-borne infections have efficiently safeguarded communities in malaria-endemic areas against foreign invaders, either military or commercial. Each of our resources is finite, and yet the mosquito performs a crucial function in the environment and therefore should be appreciated for its lethal potential. Mosquito specialist Besansky feels that killing the messenger (mosquitoes) isn't necessary to eliminate the message (disease) [5]. Therefore, mosquitoes are a significant insect group for the earth's ecosystem and management should be confined only to harmful species.

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References

1. Hadley D. What Good Are Mosquitoes? ThoughtCo, 2019. https://www.thoughtco.com/what-good-are-mosquitoes-1968303. Accessed 2 May 2021
2. Poinar GO, Zavortink TJ, Pike T, Johnston PA. *Paleoculicis minutus* (Diptera: Culicidae) n. gen., n. sp., from Cretaceous Canadian amber, with a summary of described fossil mosquitoes. Acta Geologica Hispanica,2000:35:119–128.
3. Borkent A, Grimaldi DA. The Earliest Fossil Mosquito (Diptera: Culicidae), in Mid-Cretaceous Burmese Amber. Annals of the Entomological Society of America,2004:97(5):882-888.
4. Culicidae classification. Mosquito Taxonomic Inventory, n.d. http://mosquito-taxonomic-inventory.info/simpletaxonomy/term/6045. Accessed 28 May 2021
5. Harrington J. 10 Things Mosquitoes Are Good For. 24/7 Wallst.com, 2019. https://247wallst.com/special-report/2019/08/16/10-things-mosquitoes-are-good-for/1/. Accessed 2 May 2021
6. Hada K, Kachhwaha N. Screening of green AgNPs against the larvicidal activity of Anopheles stephensi, Flora and Fauna,2020:26(1):107-112.
7. WHO. Dengue and severe dengue. World Health Organization, 2021a. https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue. Accessed 29 May 2021
8. WHO. Malaria. World Health Organization, 2021b. https://www.who.int/news-room/fact-sheets/detail/malaria. Accessed 29 May 2021
9. Dove LL. What if mosquitoes went extinct? HowStuffWorks.com, 2015. https://science.howstuffworks.com/science-vs-myth/what-if/what-if-mosquitoes-went-extinct.htm. Accessed 2 May 2021
10. A World Without Mosquitoes? It's not as great an idea as it may seem. Forest Preserve District of Will County, 2020. https://www.reconnectwithnature.org/news-events/the-buzz/world-without-mosquitoes-not-as-easy-as-it-seems. Accessed 2 June 2021
11. What Would Happen if Mosquitoes Went Extinct? Mosquito Nix, 2020. https://mosquitonix.com/blogs/news/what-would-happen-if-mosquitoes-went-extinct. Accessed 8 June 2021

12. Fang J. A world without mosquitoes. Nature,2010:466:432-434.
13. Gandhi MS. Ecological importance of Mosquitoes. Mathrubhumi.com., n.d. https://english.mathrubhumi.com/mobile/news/columns/faunaforum/ecological-importance-of-mosquitoes-english-news-1.987201. Accessed 2 May 2021
14. Lahondère C, Vinauger C, Okubo RP, Wolff GH, Chan JK *et al*. The olfactory basis of orchid pollination by mosquitoes. Proceedings of the National Academy of Sciences of the United States of America,2020:117(1):708–716. https://doi.org/10.1073/pnas.1910589117
15. Writing A. Positive Effects of Mosquitoes. Sciencing.com, 2020. https://sciencing.com/positive-effects-mosquitoes-8513632.html. Accessed 2 May 2021
16. Garland S. Mosquitoes – important pollinators? Wild Pollinator Partners, n.d. https://wildpollinators-pollinisateurssauvages.ca/2019/12/31/mosquitoes-important-pollinators/. Accessed 2 June 2021
17. Benefits of Mosquitoes. MosquitoControl.net, n.d. https://mosquitocontrol.net/benefits-of-mosquitoes/. Accessed 2 May 2021
18. Thien LB. Mosquito pollination of *Habenaria obtusata* (Orchidaceae). American Journal of Botany,1969:56(2):232-237.
19. Waterworth K. How Mosquitoes Pollinate Flowers. SFGATE, n.d. https://homeguides.sfgate.com/orchids-pollen-69362.html. Accessed 2 June 2021
20. Peach DAH. The Ecological Importance of Mosquitoes. The Wire, 2019. https://thewire.in/environment/the-ecological-importance-of-mosquitoes. Accessed 2 June 2021
21. Peach DAH, Gries G. Nectar thieves or invited pollinators? A case study of tansy flowers and common house mosquitoes. Arthropod-Plant Interactions,2016:10:497–506.
22. Statman Weil Z. *Aedes communis*: The Pollinating Mosquito. Forest Service U.S.D.A., n.d. https://www.fs.fed.us/wildflowers/pollinators/pollinator-of-the-month/aedes_communis.shtml. Accessed 13 May 2021
23. Gary RE, Foster WA. *Anopheles gambiae* feeding and survival on honeydew and extra-floral nectar of peridomestic plants. Medical and Veterinary Entomology,2004:18(2):102-107.
24. 10 Benefits of Mosquitoes: How Are They Helpful To Humans? Endmosquitoes. com., n.d. https://endmosquitoes.com/10-benefits-of-mosquitoes-how-are-they-helpful-to-humans/. Accessed 2 June 2021
25. Kasper J. Can we just eradicate mosquitoes? Museum of New Zealand Te Papa Tongarewa, n.d. https://www.tepapa.govt.nz/discover-collections/read-watch-play/science/mosquito-facts/why-cant-we-just-eradicate-mosquitoes. Accessed 2 June 2021
26. Bay EC. Predator-prey relationships among aquatic insects. Annual Review of Entomology,1974:19:441-453.
27. Benelli G, Jeffries CL, Walker T. Biological Control of Mosquito Vectors: Past, Present, and Future. Insects,2016:7(4): 52-70.
28. Joe M. What Eats Mosquitoes? The Predators of Peskiness! Mosquito Joe, 2020. https://mosquitojoe.com/blog/what-eats-mosquitoes-the-predators-of-peskiness/. Accessed 2 June 2021
29. Mizejewski D. What Purpose do Mosquitoes Serve? National Wildlife Federation, 2020. https://blog.nwf.org/2020/09/what-purpose-do-mosquitoes-serve/. Accessed 2 June 2021
30. Richter Boix A. Who eats mosquitoes? Mosquito Alert, 2020. http://www.mosquitoalert.com/en/depredadores_naturales_de_los_mosquitos/. Accessed 2 June 2021
31. Things That Eat Mosquitoes. Mosquito Magnet, n.d. https://www.mosquitomagnet.com/articles/things-eat-mosquitoes. Accessed 2 June 2021
32. What Eats Mosquitoes: The Top 10 Mosquito Predators In The South. Tuxedo Mosquito Control, 2021. https://www.tuxedomosquitocontrol.com/blog/post/what-eats-mosquitoes-the-top-10-mosquito-predators-in-the-south. Accessed 2 June 2021
33. Morello R. Are mosquitoes valuable to the ecosystem? Mom. com., n.d. https://animals.mom.com/mosquitoes-valuable-ecosystem-8494.html. Accessed 21 May 2021
34. What Would Happen if We Killed Off Every Mosquito on Earth? Barefoot Mosquito & Pest Control, n.d. https://www.barefootmosquito.com/kill-every-mosquito-earth/. Accessed 2 May 2021