Adaptations of Insects at Cloudbridge Nature Reserve, Costa Rica

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Introduction

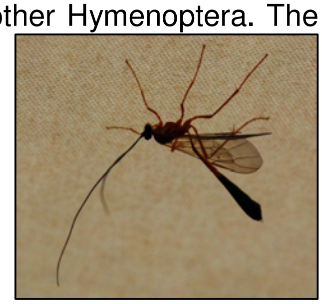
Costa Rica's location between North and South America, its neotropical climate and variety of elevations and habitats makes it one of the biodiversity hotspots of the world. Despite being only 51,100km² in size, it contains about 5% (505,000) of the world's species. Of these, 35,000 insect species have been recorded and estimates stand at around 300,000. The more well known insects include the 8,000 species of moth and 1,250 butterflies - almost 10% of the world total, and 500 more than in the USA! Other abundant insects of Costa Rica include ants, beetles, wasps and bees, grasshoppers and katydids. The following article presents a select few aspects of the insect life found at Cloudbridge, a nature reserve in the Talamanca mountain range.

Relationships

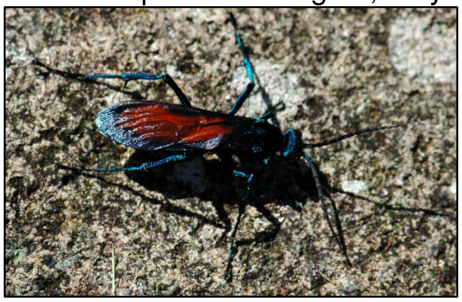
Insects play many important roles in Costa Rica, including pollination of the bountiful flora and as a food supply for many other organisms.

The adult Owl butterfly (*Caligo atreus*, shown at right) feeds on many Heliconiaceae and Musaceae (banana) species, in particular on the rotting fruit. They are pollinators of these plants, but also use the leaves to lay eggs on. When hatched, the larvae remain on the plant and eat the leaves. Being highly gregarious, they can cause significant damage, and are considered as pests (especially in banana plantations). However, there are a number of insects that parasitise the Caligo larvae, including the common Winthemia fly (left) and *Trichogramma* and Ichneumon wasps, which act as biological control agents.

There are a great many species of parasitic wasps in Costa Rica (unknown number, maybe in excess of 20,000). The majority of them are actually parasitoids, that is, they are associated with a host organism for a significant part of their lives, which they ultimately kill. Many of the adults actually feed on nectar, but lay the eggs in or on either the egg or pupa of the host species, which can be any number of insect orders including Lepidoptera, Diptera, Coleoptera, Hemiptera and other Hymenoptera. The most impressive are probably the Ichneumonoidea (see photo of male at right), whose ovipositors (female) can extend well over the length of the body. The wasp can locate its host species' larva buried within rotten wood, and then use the ovipositor to drill into the wood and lay the egg on the host. In some cases, the host may be several inches into the wood.



Some of the most intimidating insects at Cloudbridge are the spider wasps (Pompilidae). As the name suggests, these are parasitoids exclusively of Arachnids. With their powerful stingers, they can paralyse spiders much larger than themselves.



The prey is then dragged (or sometimes flown, if not too heavy) back into the burrow, an egg laid on or in the abdomen, and the burrow sealed. The well known tarantula hawk (*Pepsis* and *Hemipepsis)*, with its distinctive dark blue metallic body and red-gold wings is common around Cloudbridge. The coloration serves as a warning to would-be predators (i.e. aposematism). Although not aggressive organisms, their sting is said to be one of the most painful of the insect world; as described by the Schmidt Sting Pain Index:

"blinding, fierce, shockingly electric. A running hair drier has been dropped into your bubble bath (if you get stung by one you might as well lie down and scream)."

Watch out also for the 4-inch spider wasp, again with a blue-black body, yellow wings, and yellow curled antenna (photo at right). As described by a volunteer -- "it was rustling around in the leaves, then flew away and at first I thought it was a bird!"

Many insects are associated with one or a select few plants. Species of leaf-footed bugs (Coreidae) can often be found on the passion vine (Passifloraceae, overhanging the vivero at Cloudbridge South), on which the males use their modified hind legs for territorial combat. These pests use their piercing mouthparts to inject saliva into the plant, partly digesting the tissues, which the bug can then suck out, causing stunted growth, deformation and spreading diseases. Occasionally an assassin bug (or wheel bug, Reduviidae) can be seen prowling the passion vine for leaf-footed bugs. Once caught, the assassin bug will use a similar feeding mechanism to suck the body fluid from the prey.

Assassin bug on leaf and eating prey

Mimicry and Camouflage

Examples of mimicry and camouflage are very common at Cloudbridge. Generally, mimicry is said to be when an organism shares physical characteristics with another organism, and often confers an advantage to the mimic and is harmful to the receiver (such as a predator). It may or may not have an effect on the model. In contrast, camouflage is simply when an organism resembles part of the surrounding, such as a leaf or twig, rather than an actual organism, but the boundary between mimicry and camouflage is blurred. The term crypsis is a better description of the phenomenon of detection evasion.

Some of the best camouflaged insects are the katydids (also known as long-horned grasshoppers) and crickets which have leaf-shaped green or brown bodies. Most of these species are nocturnal, hence their incredibly long antennae (up to three times the body length). The name katydid comes from the loud male call "katy did, katy didn't," to which the female will chirp in response. Complex camouflage is shown by the lichen katydid (*Markia hysterix*, see photo below) which lives and feeds on *Usnea* lichen (old man's beard) found growing on trees, particularly in Cloudbridge North. The bizarre spikes and patterns mimic the stringy appearance of this lichen, and even its eyes are striped! On its thorax a large back spot can be seen, which may act as a decoy eye, so when birds or lizards attack, they miss the head and instead meet the large spikes protruding from the thorax.

Many of the moth species display dull coloration of brown or yellow to blend in with the leaves or bark on which they sleep during the day, making them incredibly difficult to spot. Leaf-vein-like markings and jagged, browned wing tips deceptively complete the camouflage picture. A number of lepidopteran larvae and adults even disguise themselves as bird droppings, including swallowtail butterfly larvae and the tufted bird-dropping moth.

During the night moths swarm around lights, making them easy to observe, and here it is possible to witness alternative defence mechanisms. Some species, when disturbed, will simply drop from their perch and play dead. This is very effective as most predators will only eat active prey- in the knowledge it is not dead and diseased. They may even remain still for many minutes before vibrating their wings to warm the muscles and flying back to a vertical surface. Others show more drastic methods. Those with brightly coloured hind wings, normally hidden in the sitting position, such as the io moth (*Automeris io*) pictures, will suddenly bring forward the fore wings to display red, yellow or black markings as a warning. Often these will also have eye-spots, mimicking other larger animals, startling the predator.

The owl butterflies, with large eye-spots on the underside of its wings, do not use these to scare off predators. As indicated by the name, it was previously thought that the butterfly resembled an owl's head when viewed upside down. However, a predator would have to see the creature from the underside, which never happens, especially as the butterfly sits in a vertical position with its wings closed (see previous picture). The eye-spots may serve to divert a bird attack towards its hind wings, thus saving the head and allowing the butterfly to escape. However, it has been argued that the eye-spot is actually too close to the abdomen to effectively divert an attack; the spot should be positioned nearer the wing tips. Instead, the underside pattern may resemble a *Hyla* tree frog head. This theory is supported by the fact that the main predators of *Caligo atreus* are *Anolis* lizards, which are in turn eaten by *Hyla* tree frogs. The butterflies therefore gain an advantage by mimicking their predators' predators. In any case, large butterflies can occasionally be seen flying with up to a third of their hindwings missing, showing that sometimes just diverting an attack is an effective escape method.

Sequestration of plant compounds (e.g. alkaloids) by Lepidoptera larvae, which are retained in the adult, gives them a disagreeable taste. This is signalled with distinctive black wings with red, yellow or white markings (i.e. aposematism.) Heliconid butterfly larvae feed on the poisonous *Passiflora* vines and acquire toxicity, and are therefore unpalatable to predators. Batesian mimicry is shown by a number of other butterfly species e.g. *Eresia* spp which look very similar to the heliconids, and gain the advantage of having warning colours, with no detrimental effect to a predator, if they were eaten. If you spot a heliconid, it is very likely to be one of the mimics!

To bee or not to bee? Mimicking a dangerous organism is a very effective and relatively common way to protect oneself. The bee orchids

(Euglossini) are characterised by their brilliant blue, gold or green metallic coloration. A common fly at the reserve (especially at the casa) is an orchid bee mimic, a Syrphidae (hover flies), with its metallic emerald green body and ruby under-abdomen.

Mimicry is not only used for protection, but also for predation. Asiloid flies are amongst the best mimics in Costa Rica, and include both robber flies (Asilidae) and mydas flies (Mydidae). Mydidae are generally mimics of Hymenopterans, especially wasps, and the larvae of some are thought to be subterranean predators of ants. Asilids mimic wasps and bees but predate on a wide range of insects including other flies, wasps, ants, beetles, bees and dragonflies. Their bodies are normally long and tapered, but some are bumble-bee mimics and therefore have fat, fuzzy bodies. Even the behaviour of some of these flies mimics the model. A characteristic of many parasitic wasps is that they walk over plants tapping their long antenna to detect vibrations. These flies do not have long antenna, but instead place their front legs forward and tap these to mimic the wasp.

Ants

Many ants can be seen at Cloudbridge, but the *Atta cephalotes* leaf-cutter ants are perhaps the most captivating. They can often be seen leading trails many metres long to plants and trees which they efficiently dismember and transport back to the colony for fungus cultivation. The colonies may contain more than one million individuals, and may survive for a number of decades. They are said to be responsible for 20% of the decomposition of all leaves of Latin America! In this respect, they are more important to tropical ecosystems in terms of soil aeration and nutrient recycling than the earthworms are in temperate zones.

A.cephalotes colonies consist of a number of different castes, each with a different function, and the role of a particular individual may changes as it gets older. At the centre of the colony is the queen ant, which may live up to 20 years, and lay hundreds of millions of eggs in her lifetime. The eggs are laid in the fungus chamber, and when the larvae hatch they will eat the nutrients provided by the fungus. The queen and the larvae are cared for by the gardener-nurse workers. These young minor workers stay within the confines of the nest, and undertake maintenance work and tending the fungus gardens. When a forager-excavator brings a piece of leaf back, the nest workers will drag it to an appropriate chamber, chew it up to a mulch, then remove a piece of fungus from another chamber to start growth on the new medium. As a result, the same species of fungus is propagated throughout the whole life of the colony. In fact, each species of leaf-cutter ant is usually associated with only one species of fungus, with the ant often being dependent on the fungus. It is therefore essential that any bacteria or other fungus is removed form the fungus. This is done by the gardener-nurses, who meticulously check the fungus for these foreign bodies. Any such object is swiftly removed and dumped either a distance from the nest or in the 'compost' chamber along with other waste and ant corpses.

The ants generally search for the same species of plants, knowing that the fungus can grow on it. Occasionally, a forager-scavenger will bring back a novel plant species marked with a special signal. These are handed over to a garden-worker, who will take it to a new chamber, and mulch it up, then monitor whether the fungus can grow. Once the fungus is shown to grow on the new species, the signal will be given, and forager workers will then move on to this new plant.

The foragers have powerful jaws with razor sharp processes, which effectively slice through leaves. A scissor-like action is used to remove leaf parts, with the leading mandible anchored in the leaf, and the following mandible slicing through the leaf as the jaws close. A characteristic circular pattern is cut in the leaf (picture). The ants can carry a piece of leaf 50 times its own weight over 60metres, equivalent to a human carrying 300kg over 15km, at a speed of about 26kph! Whilst an ant is carrying a leaf, it is defenceless and vulnerable to attack (*A.cephalotes* have no sting and can only bite.) Usually the soldier workers, who have enlarged jaws, protect the colony and are present in numbers effective at fighting off larger predators. However, there are some parasitoids of *Atta* ants. These include the Phoridae flies, which characteristically run to escape rather than fly (hence the name alternative name scuttle fly). These measure between ½-6mm, and most are too small to be affected by the soldiers' massive jaws. Therefore, the older minor workers sometimes ride on the transported leaf to protect the forager ant from these enemies.

The division of labour, the organisation and the efficiency of the colony in its various tasks really demonstrate a high level of evolutionary advancement. This is thanks to genetics - the workers come from the same queen, and are hence all sisters. To enable the continuation of one's own genes, it is just as profitable to help the colony as to help oneself (i.e. kin selection). It certainly provides a great example of a perfect society; the work and rewards being shared equally, something that Karl Marx would have been proud of.

Conclusion

It is impossible, in such a short piece of writing, to go into detail about all types of insects of Cloudbridge. Once there, one has only to keep eyes and ears open to spot the many delights on show. Whether it is the beetles, with endless variations of sizes, shapes, colours and roles; the leaf- and planthoppers with their unique patterns; the dazzling flashes of brilliance from the butterflies; or some of the more unusual parasitic wasps and flies; there is something here to fascinate everyone.

It is clear that Cloudbridge has a great diversity of weird and wonderful insects; highlighting the interactions, adaptations and creativity that evolution can show. It is a treasure trove of resources to discover more about the importance of insects in tropical ecosystems (and the planet's functioning), and it is likely there are novel species and useful substances still to be discovered. What is important now is to increase effort in research, and to educate people how essential the critters are to our, and the earth's, survival.

	Order	Suborder	Infraorder/Superfamily	Family	Subfamily	Genus	Species	Common name
Exopterygota	Odonata	Anisoptera						dragonflies
		Zygoptera						damselflies
	Orthoptera	Caelifera		Acrididae				short-horned grasshoppers
		Ensifera (long-horned orthoptera)		Tettigoniidae		Markia	hystrix	Lichen katydid
				Gryllidae				crickets
	Phasmatodea							walking sticks
	Dictyoptera	Mantodea						mantids
		Blattaria						cockroaches
	Hemiptera	Auchenorrhyncha (cicadas and hoppers)	Cicadoidea	cicadellidae				leafhoppers
				membracidae				treehoppers
			Fulgoroidea					planthoppers
		Heteroptera (true bugs)		Reduviidae				assassin/wheel bugs
				Coreidae				leaf-footed bugs
				Pentatomidae				stink bugs
Endopterygota	Coleoptera	Adephaga		Carabidae				ground and tiger beetles
					Cicindelinae			tiger beetles
		Polyphaga	Scarabaeoidea	Passalidae				bess beetles
				Scarabaeidae			1	scarab beetles
							2	
							3	
							4	
							5	
			Elateroidea	Elateridae		Semiotus	superbus	click beetles
				Lycidae				net-winged beetles
			Tenebrionoidea	Tenebrionidae				darkling beetles
				Meloidae		Menoe sp.		blister beetles
			Chrysomeloidea	Cerambycidae				longhorned beetles
				Chrysomelidae			1	leaf beetles
							2	
							3	
			Curculionoidea	Curculionidae	Dryophthorinae	Cactophagus	diplocinctus	snout and bark weevils
							2	
							3	
	Megaloptera			Corydalidae		Corydalus		dobsonflies (fish flies)
	Hymenoptera	Aculeata	Apoidea	Andrenidae				mining bees
				Halictidae				sweat bees
				Apidae				bumble and carpenter bees
			Vespoidea	Mutillidae				velvet ants
				Pompilidae				spider wasps
				Vespidae				paper and potter wasps
				Formicidae	Dorylinae			army ants
					Formicinae	Camponotus	planatus	carpenter ants
					Myrmicinae	Atta	cephalotes	leafcutter ants
		Apocrita		Pelecinidae		Pelecinus	polyturator	wasp-waist hymenoptera
			Ichneumonoidea	Ichneumonidae				ichneumon wasps
	Diptera	Nematocera	Culicomorpha	Simulidae				black flies
				Culicidae				mosquitoes
				Chironomidae				midges
			Psychodomorpha	Psychodidae				moth flies and sand flies
		Orthorrapha	Tabanomorpha	Tabanidae				horse flies
			Asiloidea	Asilidae				robber flies
				Mydidae				mydas flies
			Empidopidea	Dolichopodidae				long-leggef flies
		Calyptratae	Muscoidea	Muscidae				house flies