

## Life Underground and Underwater in the Forest



The underwater world of tiny streams harbors a wide variety of fish, but they can often only be seen close up at night. Photo by Bill Magnusson.

When the water level in the Amazon dropped, the fishermen pointed to holes in the bank that they said were inhabited by an eel-like animal that I later discovered was an aquatic caecilian of the family Typhlonectidae. I had never seen a caecilian, because they don't occur in Australia, but the description of these slimy legless amphibians did not spark my interest, even though there are reported to be at least a dozen species in the family. They were nearly eyeless and just poked around in the mud looking for worms and other small animals that they could find by touch or smell.

I became more interested in caecilians when I saw what I thought was a yellow worm as thick as my finger disappearing into the leaf litter in the middle of the forest. I grabbed it and was surprised to find that it was strong and agile. Not a worm at all, it was much more like the burrowing amphisbaenid lizards I had captured in the area. It had humid skin like that of a frog, and rings around its body like a worm, but its mottled yellow and black color set it out from the leaf litter. I knew that it was a caecilian and I was surprised to see that it had distinct eyes and could apparently see quite well.

The pretty little animal was a species of *Rhinatrema*. Species in the genus are considered primitive because they lay eggs, whereas most caecilians give birth to active young. Presumably, the well developed eyes are also a primitive feature, because most caecilians are almost blind. I was tempted to keep the animal in captivity to see what it ate, but I was in the field and would not have been able to look after it properly. After photographing it, I released it back into the leaf litter and watched it disappear within a few seconds.

Although there are about 200 species of caecilians, people rarely see them because they live underground or underwater. We had probably walked over thousands of caecilians in Reserva Ducke without noticing it. The only other species of caecilian that I came across regularly was *Siphonops annulata*. Large caecilians with tiny eyes appeared on walking tracks after heavy rain, and they

were easy to capture. Much larger than the *Rhinatrema*, most were thicker than my thumb and up to half a meter long. Close up, I could see that they had blue between the slatey-grey rings.



Photo 15.1 Rhinatrema sp.. Photo by Bill Magnusson.

The biggest problem was to put them in a life-like position to photograph. When in the open they were skittish and moved continually. I also despaired of getting a position in which they appeared alive. The thing that most attracts attention in a photograph of an animal is its eyes, and the eyes of this caecilian were just tiny indentations in its forehead. I also didn't have much time for photography when I was in the forest because I was generally engaged in other research.

When another researcher brought one of the grey caecilians to my laboratory in Manaus, I thought that it would be a good opportunity to get a better



photograph. The terrarium I put it in was spacious, but the animal just half heartedly dug under the thin layer of leaf litter and then lay still, showing its complete lack of coordinated movement when above ground.

The caecilian was too agitated to easily photograph when in the open, so I put it into the freezer compartment of a refrigerator to cool it down before putting it into a more natural setting for photography. I planned to leave it there for only a few minutes, but someone rushed in, grabbed my arm and said that there was an emergency outside. I still hadn't learned that people often just mean that there is something they want done quickly when they say there is an emergency, and by the time that I found that there was no urgency the caecilian had been in the refrigerator for fifteen minutes.

I rushed back when I realized my mistake, but the wet sack had frozen to the floor of the freezer and caecilian was stuck to the ice patch by skin under its neck and mid body. I used a knife to scrape the sack out of the ice, but the caecilian was apparently dead. Cursing my stupidity, I dropped it into the terrarium and went to look for formalin to preserve it. However, someone dragged me off for another "emergency" and I did not return for an hour. When I picked up the caecilian, it was limp, but managed to thrash around half heartedly. It had white patches on its underside where it had been frozen, but I decided to leave it to see if it would recover.

It was hard to tell whether it had been permanently damaged because it was so lethargic and unresponsive before it had gone into to the freezer. It had thrashed around when I tried to photograph it, but its movements had always seemed uncoordinated. I had just about given up on being able to distinguish a dying from a healthy caecilian when someone brought in another long slimy creature with rings around its body, but this time it was a giant earthworm.

Worms as thick as my finger and several feet long were common in the forest, and often came to the surface after heavy rain. I had no use for this one, but thanked the person and looked for somewhere to store it until I could release it in the reserve the following day. The best place seemed to be the terrarium and I dropped it a few hand spans from the caecilian.



*Photo 15.2 The ringed caecilian*, Siphonops annulatus, *has tiny eyes*. *Photo by Bill Magnusson*.

I was unprepared for what happened next. The caecilian reared up like a snake, arched over the intervening distance, and grabbed the mid body of the worm, which contorted and rolled until it broke in two. The caecilian gulped down half the squirming worm, which was almost as thick as its body, then went after the other half, rolling and contorting like a shark in a feeding frenzy. How this apparently blind animal had been able to accurately pinpoint its prey a body length away escaped me. When there was nothing left of the worm, the caecilian resumed its limp position along the edge of the terrarium and again looked as agile as a discarded length of rope.



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Seeing the domination of the worm made me realize that caecilians are mighty predators, and that my opinion of them as clumsy slugs pushing around until they came across something too stupid to get out of their way was a product of my ignorance and inability to see into their underground world. Each species of caecilian must be doing something different, and we are not even sure how many species there are. They probably have complex means of communicating with each other by scent, sound or touch, but our limited senses do not give us a window into their world. Maybe if I had another life I would be a caecilian biologist!



I generally trod carefully around camp, and our bare feet left little evidence of where we walked. The flat areas around streams in Reserva Ducke are sandy and moist, and the trees cannot penetrate far into the ground, so they spread their roots across the surface in a complex tapestry. In some places, the roots are not very thick and are covered by leaf litter, but you can generally hop from one support to another. When visitors came wearing heavy boots they would stomp across delicate roots leaving muddy puddles and canals that drained into the stream. They also cut the leaves of spiny palms with machetes to clear their way, and left spikes hidden in the mud, which did not please those who did not wear shoes. The visitors were generally ignorant of the life they crushed as they stomped around and I realized that it was because they could not feel the forest that they could not see it.

We walked much more slowly without shoes, but we gathered information faster. I stood for long periods just watching, and Albertina, who studied the behavior of tiny frogs, was even more patient. I would often spend time watching the stream; the soft earth squeezing up between my toes and making me feel at home. One day, I was leaning against a tree, watching the dark water flow smoothly down a long stretch without rapids or logs when a long silver fish leapt out of the water in a wide arc before splashing back in and sending ripples to both banks.



Photo 15.3 Streams much smaller than this have dozens of species of fish. Photo by Sandy McMath.

The fish had jumped in my direction and it re-entered the water for only a few body lengths before leaping again, like a bait fish trying to escape marauding tuna. The leaping continued from about 10 m downstream to about 5 m upstream, where it disappeared around a bend. I recognized it as a freshwater barracuda, *Acestrorhynchus falcatus*, a pike-like fish with huge teeth that I had assumed was one of the top predators in the stream.

I slid down the bank to try to see what had made it jump, but I saw only two grey forms about a foot long gliding over the sandy bottom followed by about a dozen smaller objects the size of a pencil. As I sank into the sand on the edge of



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the stream, I dislodged leaves in deeper water and watched them spread out into the current, but one attracted my attention. It initially floated downstream, but then went upstream against the flow until it reached a spot where the water pushed it back into the patch of leaf litter. There were obviously things going on in the stream that could not be fully appreciated from the bank and I returned to camp to get a face mask and diving light.

I did not see a lot on my first dive because I tried to swim against the current. It was only later, when I leaned to let the current take me downstream at its own pace and to hold onto a log and let the fish come to me that I began to see the variety of fish that lived in the stream. The leaf that swam against the stream was a *Monocirrhus polyacanthus*, a flat plaice-like fish that is virtually invisible in the litter banks. It swims by movements of transparent fins, so the brown body just seems to be a leaf floating aimlessly in the current.

The grey shadows I had seen from the surface were *Crenicichla cf lugubris*, long cichlids with bright red stripes down their sides in the breeding season. Each section of stream had a resident pair and their offspring.

I had read that fish that care for their young always expel the little fish from their territory before they are big enough to compete for food with their parents. However, the young fish I saw being herded were at least a third the length of their parents and must have been eating the same kind of food. I could calculate the size of their territories from the length of stream that the freshwater barracuda was forced to jump out of the water as it passed, the aggressive parents not letting it remain in the water long enough to grab one of their babies.

The cichlid *Aequidens pallidus* dug circular nests in the bottom in front of camp, and the pairs defended the eggs until they hatched. Although the fish displayed behavior that would elicit warm feelings if seen in a mammal, their actions seemed mechanical and I did not attribute any emotional significance to what I saw. Only recently, it has been shown that the social milieu in which

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they are raised determines the social competence of young fish and even the structure of their brains<sup>52</sup>. Messing up a fish society can have psychological consequences as great as social deprivation can have on people.



**Photo 15.4** The hatchet fish, Carnegiella strigata, swims at the surface and feeds on insects that drop into the stream. Photo by Bill Magnusson.

I had eaten the large loricarriid catfish that occur in the big rivers. Some of them are more than an arm's length from snout to tail and they look like prehistoric armored tadpoles. Their bony scales are fused so they are clumsy swimmers and they spend most of their time on the bottom where they scrape up algae and unidentifiable gunk. The species in Igarap é Acar á were generally less than a hand span long, but had the same armored body, with bony pectoral fins that could be spread and locked in position to make it difficult for a predator to swallow them. The *Parotocinclus longirostris* lived on fallen logs, had a wide head and short tail, and was hard to see during the day. At night,

their bright eye shines reflected our lights and made them easy to find. Up close they had tiny bluish spots that looked luminescent in the torch light. A species described from Reserva Ducke, *Rineloricaria heteroptera*, that lived on the rocks in the rapids was even more cryptic. Its long carrot-like body was the same color as the rocks, and long filaments from its tail made it look like the strands of brown alga that hung in the current.

We rarely saw knife fish during the day, but several species came out and foraged at night, especially in the deeper pools. Some were camouflaged to look like the leaves and sticks accumulated on the bottom, but other species had brown and cream bands that made the fish stand out in the beams of our diving lights.

The species that most attracted my attention literally had no color. It was almost transparent, except for the backbone and silver lining of its body cavity. At night, the fish hunted over sandbanks, head down with the body and tail held vertically so that they looked like bobbing sticks moving across the sand. During the day, they generally disappeared into the sand, and the only place we could find them active was in a few rocky caves with sandy bottoms where little daylight penetrated.

There were other sand-dwelling fish that only came to the surface at night, and *Pygidianops amphioxus*, related to the vampire fish, but not a blood sucker, was described from Reserva Ducke in 2011. Every nook and cranny appeared to have its own species of fish. Some were specialized in midwater and looked like minnows. Even the interface with the air had its own species, and hatchet fish, *Carnegiella strigata*, and leaf catfish, *Helogens marmoratus*, patrolled just below the surface at night.





*Photo 15.5* Loricariids, such as this Parotocinclus longirostris, are hard to see during the day, but at night can be found by their bright eye shines. Photo by Bill Magnusson.

If I stood still in the deeper parts of the stream, large shrimp would nibble on my toes. They looked like the *Macrobrachium* that were common in most Australian rivers and seemed to have similar habits. The females carried large eggs that gave the impression of a tiny bunch of grapes under the tail. I could see the eyes of the developing embryos and realized that the prawns in the nutrient-poor forest streams were very different from those in the Amazon River, even though they belonged to the same genus. The prawns of the sediment-rich waters produced thousands of tiny eggs that hatched into planktonic larvae similar to those of the sea prawns we like to eat. There is little food for free-floating larvae in the forest streams, and the mother prawns carry their few large eggs until the fully formed babies hatch and can wander around the bottom on their own.



By lying in the shallow water at night with a light I could watch the prawns foraging and found several species. It was cold in the water, the rocks dug into my belly, and the prawns nibbled on my bare legs, but the antics of the prawns captivated me. There were no atyid shrimps with brush-like fans sitting in the shallow fast running water as there would be in Australia or in southern Brazil. However, they were replaced by species of *Pseudopalaemon*, which looked like transparent *Macrobrachium*. They belonged to the same family and had long pincers, but their small size, lack of pigments and habit of sitting in strong currents made them hard to see. I pushed up close to the red roots hanging in the water and could see that the glass-like prawns had to hang on with all their might. The current swayed them from side to side and the vibrating roots gave poor support. Presumably, the fast flowing water brings food and keeps predators away.

Below the *Pseudopalaemon* were larger prawns of the species *Macrobrachium nattereri*; the species that had nibbled on my toes. They were as thick as my little finger and poked around in the sand and in crevices for insects or small fish that they could grab with the tiny pincers on their walking legs. The large front claws that were longer than their body did not seem to be used for hunting though they did direct small animals, such as tadpoles, under the body and into the feeding pincers.

The third species was intermediate in size and somewhat squat, with a smooth round body, short nose spike and stubby claws. Most were dark with a lighter yellow line down the back. I found them mainly in shallow slow flowing places and would later learn that they were most common in small ponds that formed around the streams in the wet season. They had been described only a few years before and carried the name of the institute I worked for. They were called *Macrobrachium inpa*.

The prawns were not the most spectacular crustaceans in the area. The low lying areas around the stream covered by a mesh of tree roots were generally dry, but when pools formed during heavy rain, freshwater crabs as large as the palm of my hand left their underground burrows. Their red and white colors stood out as they circled to keep their claws between their bodies and the large humans that were walking around when any sensible creature should be taking shelter from the tropical downpour.



*Photo 15.6* Prawns, such as this Macrobrachium nattereri, often nibble on your toes when you stand in the stream. Photo by Bill Magnusson.

I intended to study the reproductive cycle of *Macrobrachium nattereri* and collected specimens for a year, but another researcher complained that I should not study reproduction of prawns because she was an expert on evolution of the group. I gave her all my specimens and never returned to the study of crustaceans. However, I think that if I did, I would study the freshwater crabs that spend most of their time in an underground world about which we know essentially nothing.





There were fish in even the tiniest of streams and I couldn't name most of them. A lot was known about the fish in the large Amazonian rivers because many species were fished for food and most of the others came as bycatch. However, few researchers were interested in the fish in the tiny streams that drained the forest. Luckily, one who was, Jansen Zuanon, worked for INPA. He had initiated a project called *Igarap és*, which means streams in Brazilian Portuguese and had already surveyed many places around Manaus. He agreed to co-supervise a student, Fernando Mendonça, to learn about the fish of the Ducke streams.

Jansen's method basically consisted of isolating a stretch of stream with fine nets and then searching it thoroughly with scoop and seine nets. He had originally used larger sections, but we decided to use 50 m stretches of stream to investigate the relationships between stream characteristics and the fish fauna in Reserva Ducke. That ended up being the standard for surveys in other areas in the following years<sup>53</sup>, and Murilo Dias used it to detect environmental impacts of forestry<sup>54</sup>.

Fernando tried supplementary techniques, such as searching the area at night with a headlight and detecting knife fish by their electric signals, but the extra species detected did not change any of the major conclusions and we no longer use them routinely. It was fun pushing the nets up under the banks and sorting through the debris for fish, most of which were tiny and would have gone unnoticed even if they had been swimming in open water. In the net, most looked nondescript, but when we put them into plastic bags or small aquariums we could see that they had bright colors and the variety of shapes was amazing, the fish seemingly imitating almost everything in the stream, from sandy particles, to sticks to leaves to pieces of bark on fallen logs.



*Photo 15.7* Freshwater crabs are common around Igarap éAcar á, but are generally only seen on the surface after heavy rain. Photo by Bill Magnusson.

On average, Fernando collected nine species of fish in each 50 m segment. That is more species than you would find in the whole length of many Australian rivers, and about the same number per stretch that you would find in rivers of the southeastern USA. I had seen that many species in short dives in the larger streams, but I had not expected to find so many in the tiny streams that were only a hand span wide and less than a finger thickness deep. Fernando found 49 species in Reserva Ducke during his initial study<sup>55</sup>, and more than 60 species have been collected in the reserve up to now<sup>56</sup>. Considering that Reserva Ducke is only 10 x 10 km, that is a lot of species. Even in places with diverse fish faunas, you would have to sample a much larger area to find as many species in most regions of the World. I had not seen that many freshwater species in all the years I had fished in Australia.



Fernando only surveyed the streams, but we had seen many fish in the small pools that formed during the wet-season, some of which held water all year round. Victor Pazin studied the pools beside the same streams and found that many of the species that were apparently rare in the streams spent most of their lives away from the main channel<sup>57</sup>. He found 18 species in the ponds, most of which also occurred in the streams, but there was no relationship between the types of fish in the pools and those in the adjacent stream, so it was not just a case of stream fish being accidently washed into the surrounding pools.

At first, we thought that the fish were totally dependent on floods to get to and from the pools. However, one day I was hiking up a hill we called *ladeira verde*, which means green slope. It merited a name because it was one of the hardest climbs along the road to our camp. It was too steep and slippery to be traversed on a motor bike, even with off-road tires. Few students managed to walk up it the first time without falling over, and one dislocated his knee when he slipped. There were pools in the tire ruts in the road on the top of the hill that were used by frogs, but at first there were no fish there.

I was walking up the *ladeira verde* during a thunderstorm and a thin layer of water formed over the hard clay soil, which made walking difficult, so I plonked my heavy pack onto a log and took a break. As the rain eased, I saw what I thought were crickets jumping up the road and I kneeled to get a better look. What I had taken to be insects were small fish flipping themselves up the hill. They were species of *Rivulus*, which belong to the family Rivulidae; famous for the rain fish which appear in isolated puddles after rain. Some species in the family lay eggs that are resistant to drought and that hatch after rain, but the species in Reserva Ducke do not have resistant eggs and have to jump across the ground to get to and from isolated pools. The pools on the ridge ended up having many fish even though they had no direct connection to the streams and were about 60 m vertically above them.





*Photo 15.8* Students learning how to sample fish in small streams. Photo by Bill Magnusson.

Helder Esp fito-Santo studied the migrations of the fish between the streams and the adjacent floodplains<sup>58</sup>, and showed that the flood pulse was as important for the small streams as for the large rivers studied by Wolfang Junk. Helder's study required that the same sections of stream be surveyed multiple times, and we became concerned about the effect of taking so many fish repeatedly from a limited area. Helder therefore carried out an experiment. Instead of just collecting all the specimens, as is standard practice in most studies of small fish, he collected all the fish from only half of the sites the first time. In the other stretches, he identified the specimens from a photographic guide and released them back into the stream<sup>59</sup>. His study showed that taking the fish had no detectable effect on the assemblages, but, more importantly, that it was not necessary to collect most of the species. Identifying and releasing could save thousands of tiny lives at no cost to the scientific conclusions.



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The studies of Fernando, Victor, Murilo and Helder showed that the assemblages of small fish in forest streams are not only diverse in species and morphology; they are part of complex ecological interactions that connect the streams and the surrounding riparian areas. Streamside areas are the first to be impacted when humans colonize an area, and freshwater-fish species are among the most endangered taxa throughout the World. Partly, this is because streamside areas are of great utilitarian value, but I suspect that our lack of care also reflects that we are generally most preoccupied with the fate of land vertebrates, and the most common vertebrates in the streams are fish. When we think of fish, we first think of food and sport and only secondarily how fantastic they are. They say that beauty is in the eye of the beholder, but in the case of fish it seems to be restricted to the taste buds.

I thought of a script for a movie, but it would be too horrendous to be shown. Imagine aliens that lived in a watery extra-galactic world before colonizing Earth. They couldn't hear in air, but communicated with the fish and other animals in the sea. One of their favorite pastimes was to send invisible feelers with hasps on the end out onto land. The hasps were covered with food that the humans swallowed. When the sharp steel punctured their intestines, the humans started screaming in agony and running around madly, but the aliens couldn't hear them and assumed they felt no pain. The humans weren't killed immediately but left to gasp out their lives underwater. If the alien caught a child, it would pull out the hasp, often with an eye or a half a jaw attached, and throw the screaming child back onto land to grow bigger for the next catch. If it had been able hear the screams, the alien would never have been so cruel.





*Photo 15.9* We generally think of fish this way, but they were far more beautiful swimming in the river. Photo by Bill Magnusson.

Sounds horrible doesn't it? Now substitute alien with human and human with fish and you know what I'm talking about. I'm no bleeding heart and don't mind people who fish for food as long as they dispatch their victims quickly. However, I must admit that sport fishing, which is done just for the pleasure of torturing the poor animal and showing off to your beer swilling buddies, does turn my stomach.

