# The Purus-Madeira Interfluve:

## Lessons on the Functioning of the Amazon Forest

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## **The Purus–Madeira Interfluve:** Lessons on the Functioning of the Amazon Forest

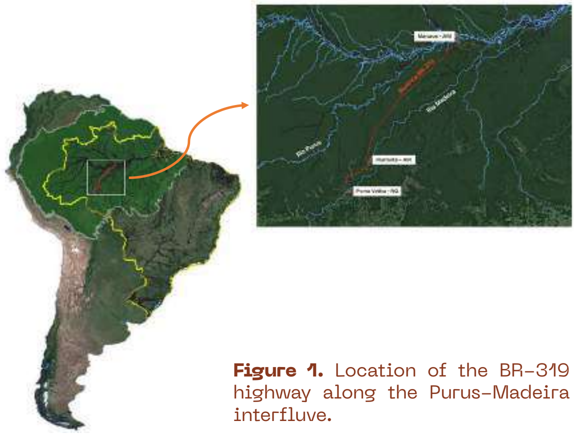

**Figure 1.** Location of the BR-319 highway along the Purus-Madeira interfluve.

### Earth and Water

The large rivers Madeira and Purus flow parallel to each other over most of southwestern Amazonia, and the land between them is known as the Purus-Madeira interfluve. The region has been sparsely inhabited by human communities since the decimation of almost all indigenous peoples by disease, warfare, and enslavement prior to circa 1700. Since the 1970s the area has been undergoing a new phase of occupation which is due to the construction of the BR-319 highway. However, only a few years after its construction, the lack of maintenance rendered it impassable for small vehicles for most of the year. Despite many proposed restoration projects, the highway has never been effectively restored, but these plans for restructuring and paving it raise significant concerns about conserving the surrounding forest.

This region is home to an enormous variety of animals and plants as well as a wide range of soil types and rainfall patterns. These factors need to be taken into account when considering the restoration of the BR-319. Certain adaptations that enable the occurrence of lush forest in this part of the

**Figure 2.** Flooded forest floor during the Amazon rainy season.

Amazon can provide insights on how to improve the road with less impact on the environment around it.

This interfluve is a low-lying, flat area between two rivers. It is prone to flooding and inundation by rainwater for an extended period of the year. The slow drainage and flow of water across the land without defined channels, known as laminar flow, causes the soil to become oxygen-deprived preventing plant roots from growing down into deeper soil layers. Trees and other plants and animals have evolved and adapted to cope with shallow, oxygen-deprived soil and periodic flooding.

## The adaptations of the forest

The Amazon rainforest contains a wide variety of plants, many of which have adapted to the poor soil conditions in the region. One adaptation that is common in the Amazon

**Figure 3.** Root of an adapted tree. Note that it is a superficial root and with the help of fungi it manages to take advantage of the nutrients left by the decomposing leaves to grow.

is the formation of mycorrhizal relationships. Mycorrhizae are fungi that have a symbiotic relationship with the roots of plants. In this mutually beneficial relationship, the fungus colonizes the root system of the plant and helps the plant to absorb nutrients from the soil, while the plant provides the fungus with carbohydrates.

The partnership between plants and fungi is a vital part of the Earth's ecosystem and it is likely that this partnership dates back to the very earliest days of plant life on Earth. Tree roots have tiny threads called "root hairs." These root hairs are delicate, relatively short, and not very efficient at absorbing nutrients. It's likely that the earliest plants that colonized the Earth's surface didn't even have roots, let alone root hairs. They probably acquired nutrients from the soil with the help of fungi, but this came at a cost: the plant provided the fungi with the sugars they needed to survive, which were produced through the process of photosynthesis.

**Figure 4.** Mycelium of a fungus surrounding dead vegetation on the forest floor.

The part of a fungus that is generally visible is the fruiting body and may be edible or poisonous, but in either case, this part is the tip of an iceberg which consists of a vast network of filaments called hyphae. A significant portion of the forest is made of and relies on fungi to stay alive. Fungi play a crucial role in nutrient cycling, breaking down organic matter, and facilitating nutrient absorption by plants.

## The forest and the fungi

Some species of fungi, such as the yeast used to produce bread and beer, have very small and simple bodies, consisting of just a single cell. However, most fungi are complex and multicellular; consisting of a mass of microscopic interconnected threads or hyphae, called mycelium, that grow very quickly, and form an invisible network in the soil or the remains of other organisms. Although usually completely hidden within their substrate, the bodies of fungi

**Figure 5.** Wood decomposing fungus on a fallen tree trunk.

can be quite large, and some species are considered to be the largest individual organisms on the planet. Their fruiting bodies solely serve to ensure the production and dispersal of the spores that fungi use for reproduction.

This network of fungal mycelia is possibly the most significant communications network on the planet, and it is globally much more important than human television or internet networks. Here, we are only considering some of the functions of fungi in relation to plant survival, but their intricate and extensive mycelial networks are essential for the health and balance of ecosystems worldwide, making them a vital component of life on Earth.

Fungi play a critical role as forest cleaners. Their unique abilities allow them to break down tough plant materials that few other organisms can digest. Fungi secrete enzymes capable of decomposing lignin and cellulose, the rigid molecules that give plants their structure. While some

**Figure 6.** Root developing horizontally in search of nutrients instead of penetrating the soil.

bacteria in termite and cow digestive systems can slowly digest cellulose, they cannot penetrate the dense lignin networks in fallen trees and branches. Without wood-decomposing fungi to recycle woody debris, the forest floor would become impassably littered with dead logs, creating a tinderbox primed for catastrophic wildfires. As fungi digest dead wood, they release the carbon and nutrients locked inside, returning them to the soil where trees and plants can access them again. So the next time you traverse effortlessly through the forest, take a moment to appreciate the unseen fungal network beneath your feet that makes your journey possible! By unlocking the nutrients in fallen trees, fungi keep the forest floor clear and fertile.

The second function is especially crucial for plants, including for those that inhabit the Purus-Madeira interfluve. The forest is teeming with mycorrhizal fungi that grow on the roots of trees and when surface waters drain and oxygen returns

**Figure 7.** Leafless opportunistic plant on the forest floor.

to the deeper soil layers, it's these invisible organisms that help nourish the plants by spreading rapidly through the soil in search of nutrients that can be passed on to the plants in exchange for sugars. For the forest, this is an excellent economic strategy for both plants and fungi; they help each other, and everyone benefits because producing mycelia requires much less energy than growing long and deep roots.

If you take a look at the roots of a fallen tree in the Amazon rainforest, you'll see that they haven't usually penetrated very far into the soil in search of nutrients, a time-consuming and energetically costly process; instead, they have grown and spread horizontally, just below the surface.

In the forests, there are non-photosynthetic, leafless "opportunistic" plants (sometimes called saprophytes) that form associations with mycorrhizal fungi and live by taking sugars produced by other plants that are passed on by the

**Figure 8.** Stemless palm tree full of fallen leaves from forest trees.

fungus. It seems that wherever there is production, there are always profiteers; someone somewhere wanting to take advantage, without making a contribution.

Another curious survival strategy of plants can be easily observed in stemless palms. They capture fallen leaves before they reach the ground. These species, whose trunks are hidden underground, produce enormous leaves that form something resembling a seive, accumulating the leaves that fall from trees. These accumulated leaves are an important source of nutrients, and to utilize them the palms send their roots upwards, above ground where once again, the successful partnership between plants and fungi comes into play. If plants only relied on their roots and simply sent their roots upwards the delicate root hairs would dry out and be incapable of penetrating deeply into the dead leaves. Mycelia colonise the leaves, capturing the nutrients, and deliver them to the palms before they can fall to the ground.

**Figure 9.** Furrows formed on the forest floor.

Above ground, the relationship with mycorrhizal fungi is even more critical! This strategy is not exclusive to stemless palms. Most plants in the Amazon rainforest also have surface roots that grow above the ground where they work with fungi to extract nutrients from fallen leaves, branches, and trunks that lie on the surface. This can be seen in some areas where nearly all the roots are above the ground, among the fallen leaves and branches. In such places, trails used by people have carved out furrows in the ground, making it appear as though we are walking in small valleys a hand-span or more in depth. There are few roots below this level and in these locations, almost the entire forest, including the roots, grows above the mineral soil, primarily relying on fallen leaves, branches, and trunks. It's soil created by the forest itself!

The forest's ability to create and consolidate its own soil is crucial, especially along the western edge of the Purus-Madeira interfluve, where the combination of unstructured soils and frequent storms leads to many tree falls, resulting in a continuously regenerating forest. Without the protection of the forest, soils would erode, and their nutrients would be quickly carried away by water.

## The network of interdependencies in the forest.

Forest trees in the more flood-prone areas along BR-319 exhibit faster growth and higher productivity during years with limited rainfall. Conversely, trees in drier regions thrive during rainy periods. Saturated soils often support a different array of plant species than drier soil areas, but there's a significant overlap in species, prompting questions about the role of mycorrhizal fungi.

Studies conducted in temperate zones of the northern hemisphere suggest that fungi play a pivotal role in maintaining forest diversity. They facilitate the transfer of energy from trees adapted to specific seasonal conditions to trees less suited for those conditions during the same time frame.

This leads to a crucial question: Do mycorrhizal fungi perform a similar function in the Purus-Madeira interfluve? Do they transfer energy from trees adapted to wetter soils to those adapted to drier conditions in rainy years and vice versa in drier years? If the answer is affirmative, it indicates that fungal-mediated interactions between tree species in the Amazon rainforest are even more intricate and multifaceted than previously recognized.

The interaction between plants and animals is also a crucial component of this complex network of dependencies that sustains the richest biodiversity on the planet. In the Amazon rainforest, competition among plants for nutrients could potentially result in the dominance of a few species. However, within the forest, numerous animal species exist, with some specializing in consuming plants (herbivores). These herbivores contribute to the maintenance of biodiversity by preventing any single plant species from monopolizing the landscape. Additionally, there are others that specialize in consuming other animals (carnivores), which helps control herbivore populations. Forest life represents an incredible network of cooperation and interaction.

**Figure 10.** Roots adapted to waterlogged soils. These roots grow above the inundation level to get oxygen.

## The forest communication network

We still have a lot to learn about how plants, animals, and fungi communicate. It's likely that we often underestimate the communication abilities of other species, possibly due to lack of imagination.

Some plants can perceive the sound of their pollinators and produce more nectar when they are nearby. Some trees can detect when others are being preyed upon by leaf-eating insects. Studies with peas have shown that they can perceive the sound of running water, directing their roots toward the sound when the soil is dry but ignoring it when soil moisture is sufficient. If a small, short-lived herb can exhibit such abilities, one can only imagine what a centuries-old tree might be capable of.

**Figure 11.** Bee pollinating a flower.

An even more intriguing example occurs when the leaves of some plant species are attacked by aphids. In response, the roots of the plant release L-DOPA, the same chemical used for communication between nerves in our brains. Neighbouring plants of the same species detect this chemical signal through their roots, which then stimulates them to produce more of this substance. This chemical is subsequently transported to the leaves, where firstly, it reduces the nutritional quality of the leaves, making them less appealing to aphids. Secondly, it increases the production of defensive compounds that can directly harm aphids, and thirdly, L-DOPA has been found to attract beneficial insects, such as wasps that parasitize the aphids. These examples illustrate that plants and animals, which we often envision as solitary entities, are in constant communication, benefiting one another.

Some fungal species have the potential to cause diseases and even kill trees, especially when there is a breakdown in communication between them. Mycorrhizal fungi tend to form associations with specific tree species, and a fungus that benefits one plant may be detrimental to another. As a result, trees and fungi must communicate to distinguish between friends and foes. There is evidence to suggest that they communicate through electrical pulses, akin to the electrical signals our nerves use to transmit messages throughout the body. Additionally, they can employ chemical communication, involving odours or substances dissolved in water, similar to our sense of smell and taste.

Some species employ chemical communication to deceive plants, and this is particularly evident in certain fungi that typically live above ground, often at eye level. While some of these fungi capture only falling leaves within their web-like structures, the 'deceiver' fungus takes advantage of the twigs of smaller, lower plants to support a network formed by their mycelia. In normal circumstances, plants extract most nutrients from leaves before shedding them to the forest floor. However, these fungal species extend their mycelia

**Figure 12.** Sick leaf due to fungus.

along branches until they locate a living leaf. Then, they release the same hormone that plants use to shed a leaf, causing it to drop into their network of mycelia, while still rich in nutrients. The actions of these fungi are akin to those of herbivorous animals that feed on living plants.

## The flooded forest and laminar flow

Animals also need to adapt to the surface water that frequently floods the forest, especially in the interfluve. For example, some species of leafcutter ants are well-known for their enormous underground nests. However, these species cannot thrive in the low-lying areas of the Amazon where the soil remains flooded for much of the year. Leaf cutters rely on the fungus they cultivate as a food source to sustain their colonies, and the fungus requires spacious, well-ventilated chambers for cultivation. In regions of the Amazon prone to frequent flooding, some species of leaf-cutter ants seize the

**Figure 13.** Net made by fungus to catch falling leaves before they reach the ground.

opportunity provided by stemless palms, which are adapted to retain and accumulate dead leaves. They use small leaves and twigs to construct their nests on these palms.

At first glance, the nest appears to be a collection of leaves randomly accumulated by the palm. However, upon closer inspection, it becomes clear that the small pieces of leaves and branches have been cut to a uniform size. When the nest is underground, it is a challenge to examine the complex structure, but here, by carefully removing a small section of the nest wall, we can see the fungus. Healthy fungus exhibits a golden colour and has intricate cavities, like gourmet cheeses. In contrast, if it has been infiltrated by other fungi and subsequently discarded by the ants, it takes on a bluish hue.

Many other ant species also construct their nests in bushes and trees. Some ants even plant seeds of epiphytic plants (plants that live on the branches and trunks of other plants),

**Figure 14.** Leaf-cutter ant nest built on a stemless palm.

**Figure 15.** Ants hunting on the water surface.

providing ants with both food and nesting space; the roots help consolidate the nest walls.

A common adaptation among ants in regions prone to flooding is for one ant to grasp onto another, forming rafts with their bodies to support the queen and eggs until the water recedes.

Interestingly, in the Purus-Madeira interfluve, ants have been observed hunting on the water surface in situations where they could have avoided entering the puddle. This behavior has not yet been documented in other areas, and there are likely numerous other adaptations that organisms employ to survive in flooded environments that remain to be discovered.

Some species of spiders are found exclusively in flood-prone areas. They look like your average ground-dwelling forest spiders, but when water levels rise, they remain on the surface or near the water's edge with their two front legs extended. This enables them to sense the movements of their

**Figure 16.** Spider "fishing" on top of the water that floods the forest floor.

aquatic prey. Upon detecting vibrations, they seize their prey with their legs, occasionally capturing small fish. When threatened, some species can escape underwater, surviving with the help of an air layer trapped within the bristles that cover their bodies.

Interestingly, there are aquatic butterfly caterpillars which employ a similar strategy, maintaining an air pocket among their dense hairs to facilitate breathing.

While it may hinder tree growth, the layer of water that covers the forest floor during rainy periods is highly beneficial for aquatic organisms. It aids the decomposition of fallen plant material within the forest and encourages algal growth on submerged trunks and leaves. During this time, various species take advantage of the shallow water to feed and reproduce. This phenomenon relies on something called laminar flow, which typically occurs in shallow areas. In laminar flow, water moves smoothly in a single direction,

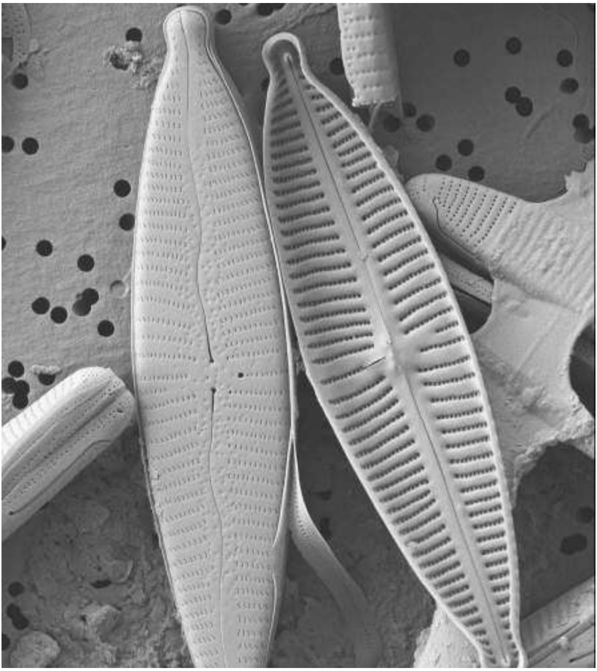

**Figure 17.** Diatom algae as seen through a microscope. (Credit: Fabiane Almeida).

resulting in clear water with minimal suspended materials, such as clay, sand and plant debris. The clear shallow water enables sunlight to reach the bottom, providing nourishment for tiny algae known as diatoms. These consist of single cells enclosed in a silica shell, creating intricate forms visible only through a microscope.

During the rainy season, numerous puddles form on the forest floor, serving as both shelter and breeding grounds for a variety of species. When these pools are isolated and distant from the streams, they usually don't contain fish, allowing some frog species to exploit them for tadpole rearing.

A sequence unfolds in the arrival of frogs at these pools. Firstly, foam-nesting frogs arrive, patiently awaiting the water's arrival and then later, as the pools fill up, different frogs lay many small eggs some of which may serve as sustenance for tadpoles. Given the abundance of nourishing bacteria and algae in these pools, females do not need to

**Figure 18.** A toad during its reproductive period near a puddle in the rainy season.

equip their eggs with copious nutrients. Consequently, the larvae develop swiftly, progressing to the juvenile stage.

Most frogs need moist, wet, or damp environments, but almost every frog species has a unique reproductive strategy. Some lay only a few eggs and utilize small puddles in or on tree trunks or at the base of plant leaves. Others deposit their eggs high up, encased in leaves, foam or within a gelatinous mass where they hatch and the tadpoles subsequently fall into the water. Certain species boast brilliantly coloured tadpoles, signalling to predatory fish that they are unappetizing or toxic.

Once they reach adulthood, frogs typically consume insects and other invertebrates to acquire energy and produce new eggs.

The use of these pools is not exclusive to frogs and toads. They are also utilized by females of many mosquito species that seek blood to sustain the enormous number of eggs they

**Figure 19.** Dragonfly larva, one of the predators that can be found in puddles.

deposit in the pools. As we are one of their preferred sources of blood, mosquitoes can be quite a torment at the beginning of the flood season when many isolated pools form.

The colourful adult dragonflies often capture our attention, but it is their larvae, typically grey and resembling dead leaf fragments beneath the water's surface, that exert the greatest influence on these pool ecosystems. Usually, they are among the initial predators to colonize isolated pools, preying on mosquito larvae and potentially eradicating them entirely.

Once the forest is largely inundated, the larvae of insects and tadpoles of frogs draw enormous numbers of larger aquatic predators. Crabs, shrimp, fish, and other water-dwelling creatures appear. Though crabs were present all along, they conceal themselves in burrows when water levels drop.

## The forest in the dry season

The topography and climate of the Purus-Madeira interfluve frequently cause many streams to dry out when there is little

**Figure 20.** A species of fish from the family Rivulidae that can move on the ground.

rain, often leaving just a few murky puddles in the deeper parts of the channel. Some fish have hardy eggs or other adaptations enabling them to survive in mud when water flow ceases. For instance, swamp eels (*Synbranchus* sp.) can breathe with the lining of the mouth and pharynx when moving about on land and adult killifish leave resistant eggs to hatch when the water returns.

Other species migrate to larger, perennial streams as smaller ones dry up, returning to newly inundated areas when water levels rise. However, little is known about most species' biology or how they survive and interact in an environment that alternates between aquatic and terrestrial.

## The forest and its relationships that seemed unlikely: bacteria, termites and caimans

**Figure 21.** A one-gilled eel that can breathe air.

The only species of caiman common in the interfluve forest is Schneider's dwarf caiman (*Paleosuchus trigonatus*). Cuvier's dwarf caiman (*Paleosuchus palpebrosus*) occurs mainly in borrow pits created during the construction of the BR-319 highway, and the spectacled caiman (*Caiman crocodilus*) and black caiman (*Melanosuchus niger*) occur near large rivers. In general, species of caimans and other crocodilians do not occur in small streams in continuous forest, because they need the sun to warm their nests. The sex of caimans depends on the temperature at which the eggs are incubated, and if the nests do not reach sufficiently high temperatures, only females will be produced. Studies carried out on Schneider's dwarf caiman in other regions indicate that this species can reproduce in the forest because it builds many of its nests next to termite mounds, and the heat generated by the termites warms the eggs to temperatures that produce males. Termites depend on the bacteria in their intestines to digest the wood they feed on, and the heat resulting from this

**Figure 22.** Schneider's dwarf caiman eggs near a termite mound.

digestion process warms the nest and provides incubation temperatures suitable for the production of both sexes.

Were you aware that the sex of caimans sometimes depends on termites and bacteria? If you answered "no," you're likely part of the vast majority. But now that you do know the answer, you can imagine the number of relationships that exist within the forest that we have yet to understand or perceive. We do not know how many links in the forest ecosystem can be severed before it plunges into a state of collapse, but we do know that almost nothing remains after the forest has been cut down and burned. When we devastate one of the planet's most vibrant ecosystems, teeming with diverse species and ingenious natural solutions, transforming it into a barren biological wasteland, we risk losing a multitude of potential answers to our everyday challenges. The loss is not just environmental, but a profound blow to our collective wisdom, potential, and future.

## The BR-319 and the Purus-Madeira interfluve: lessons from the road

The BR-319 highway traverses a broad expanse of central Amazonia, offering an opportunity to gain a deeper understanding of the relationship between climate and forest. Salts are chemical compounds, and sodium chloride - the most common in our diet - is vital because sodium plays a crucial role in various physiological processes, including neuron function and osmoregulation. For carnivorous animals, obtaining sufficient sodium is usually not a problem, as their meat-based diet often provides the necessary amounts. However, for some herbivorous animals, acquiring adequate sodium from their plant diet can pose a considerable challenge. Those fortunate to reside near the sea have less difficulty in this regard, as the sea breezes continuously transport salt to the land, depositing it

**Figure 23.** Clouds laden with rain along the BR-319 highway.

via rainfall. However, for animals living far from the coast, getting sufficient salt presents a challenge.

To understand why there is a lack of sodium in most parts of the Amazon we first need to consider a well-known weather phenomenon known as "flying rivers". They form when the forest areas that are closer to the sea transpire large amounts of water received as rain from the Atlantic Ocean. The transpired water forms clouds that are translocated further west before depositing the moisture as rain. The process continues with the water being recycled between the trees and the atmosphere many times until they reach the Andes.

Without this service, the Amazon as we know it today would resemble a desert. The flying rivers not only provide water to the western Amazon; when the clouds encounter the Andes, they are diverted to the most productive agricultural areas of Brazil. If the flying rivers are interrupted by deforestation this could have a profound impact on Brazil's economy. With

**Figure 24.** Moth feeding on a person's sweat.

less rainfall in the agricultural regions crop yields would decrease dramatically, leading to grave economic losses.

Researchers discovered the flying rivers through complex chemical analyses, but we can easily perceive their effects during a trip along the BR-319. In the eastern region, near Manaus, sea salt is brought by the winds and falls in the rain. However, the trees only recycle the water and not the salt, so the sodium content in the flying rivers reduces as you move west. An indication of this is the enormous quantity of bees and other insects that are attracted by people's sweat and often hinder work in the forest in the western regions. As people eat a lot of salt, their sweat is a source of sodium for these insects. This insatiable hunger for the salt from our bodies may be an indication of how much rainwater has been recycled by the forest as we move west.

## The rains and the road

During the rainy season, billions of litres of water pass over the forest floor, but as the water flow is laminar, it only flows over the roots and does not undermine the trees, which are much more threatened by strong winds in this period. This leads us to the question, why is this same water so damaging to the road? The answer is simple: the engineers were not concerned with maintaining the laminar flow that occurs naturally within the forest.

Brazil has very good laws aimed at protecting the environment, the well-known "Forest Code". One of the pillars of this code is the concept of Permanent Protection Areas ( APPs), which restrict construction in environmentally sensitive areas. For example, it is forbidden to build houses in steep areas, but every year, in the rainy season, hundreds of deaths occur due to landslides in Brazil. It is predictable that this number will increase year after year with climate change. This is a challenging social issue to resolve, but it could be mitigated if governments did not overlook APP guidelines and thus permit these tragedies. This underscores the gap that often exists between legislation and its enforcement.

The banks surrounding rivers and streams also fall under Permanent Protection Areas (APPs), and any intervention in these areas should be kept to a minimum. The breadth of an APP around a river or stream is contingent on its size, but it invariably exceeds the width of the primary channel. Engineers involved in formulating the Forest Code determined these widths with an aim to maximize laminar flow. Consequently, during floods, most of the water should not rush turbulently and destructively into the primary channel of a river. Instead, it would maintain laminar flow in the protected areas surrounding the channel, mirroring natural occurrences. When a road needs to traverse a water body, the most effective way to maintain laminar flow is to construct a bridge that spans over both the primary channel and the designated width for the APP. This approach respects the natural hydrology of the area, minimizes environmental impact, and reduces potential flood risks. It is an example of how thoughtful engineering can work in harmony with environmental conservation efforts.

Unfortunately, there is a loophole in the legislation that allows for interference in the APPs not foreseen by the

**Figure 25.** Areas around streams that are included in Permanent Protection Areas (APPs).

forest code, when the subject is considered to be "of public interest". This loophole is necessary, otherwise it would not even be possible to build bridges within APPs. However, engineers usually take advantage of this gap to completely disregard the area that should be preserved. For example, road builders often use earthworks and bury the APP, and when the watercourse is small, they often bury this too, only letting the water run through culverts. When the watercourse is larger, they build bridges only over the main channel, blocking the laminar flow in the APP.

This practice highlights a significant issue: the exploitation of legal loopholes to bypass environmental protections. While it's true that some degree of flexibility is needed to allow for necessary infrastructure projects (such as bridge construction), this should not be used as an excuse to disregard environmental considerations entirely. It's crucial that any exceptions made for "public interest" are carefully evaluated and managed to minimize environmental harm. For example, this could involve stricter oversight of construction projects, tighter regulations on what qualifies as "public interest", and greater use of environmentally friendly construction techniques. Ultimately, it's a matter of balancing the need for infrastructure development with the equally important need to protect and preserve our natural environment. It's a challenging task, but one that is essential for the long-term sustainability of our planet.

This is not a problem unique to the Purus-Madeira interfluve! We frequently see news reports about bridge collapses throughout Brazil. In some cases, a bridge is toppled because the access ramp that blocks the Permanent Protection Area (APP) funnels all floodwater towards the supporting pillars. The water's turbulence erodes the ground around them, eventually causing them to fall. Often, it's not even the bridge that falls, but the access ramps that were blocking the water flow. Either way, the disregard for the Forest Code results in high economic losses for society, and often people lose their lives! All because of the "public interest" that allows these loopholes in the law. Who is the "public" of interest in these cases? Generally, it's the earthmoving companies that are paid to repair the road until the next flood. This highlights a systemic problem where short-term economic interests are prioritized over long-term environmental sustainability and public safety.

The situation is much more complicated in the Purus-Madeira interfluve, where BR-319 is located, as surface runoff is much greater than in less flat and rainy areas. The road essentially acts as a massive dam, holding back water for tens of kilometers. Even if the water doesn't directly erode the road, it seeps into the clayey soil beneath. When a clay grain absorbs water, it greatly increases in size. The pressure due to the swelling of a grain is negligible, but the strength of the billions of clay grains that form part of the road is frightening. The process of shrinking during the dry season and expanding when wet can even split the road in halves, as if a giant had sliced through it with a knife. Photographs of the cracks in the BR-319 are very similar to those seen in earthquake movies.

**Figure 26.** Bridge collapsed and lives lost due to lack of respect for the forest code and maintenance of Permanent Preservation Areas (APP).

What is the solution? The forest indicates that the best solution is to stay suspended above the ground, not to dam the water and not to block the laminar flow. Perhaps the most economical solution in this sense would be to build a railway with tracks suspended above the ground, as proposed by renowned ecologist Phillip Fearnside in the previous century. To repair the existing highway without incurring constant damage, a modernization of the current engineering practices is necessary. This would involve building bridges over all streams, rivers, and their Permanent Protection Areas (APPs), and using elevated roads - essentially low bridges - over all areas prone to periodic flooding and surface runoff.

The forest has been thriving under these conditions for thousands of years. By studying and learning from its resilience, we could create more sustainable and durable infrastructure than traditional earthworks, which only last a few years and continually drain public resources.

## Who we are?

We are a small group of researchers who have been conducting studies along the BR-319 highway in the Purus-Madeira interfluve. What unites us is our shared interest in understanding the mechanisms that sustain the planet's richest biodiversity.

The information contained in this book is part of the results of dozens of studies that have been carried out in the past by various scientists and graduate students, and supported by many different projects, including the following:

• Western Amazon Biodiversity Research Program (PPBio-AmOc);

• INCT Center for Integrated Studies of Amazonian Biodiversity (INCT – CENBAM);

• Biodiversity survey planning and monitoring of ecosystem processes for the scientific inclusion of rural communities along BR-319 in the State of Amazonas (PRONEX/FAPEAM/CNPq - 16/2006, awarded to William Magnusson);

• Ecological and historical factors in the evolution of the Amazon biota: molecular and phenotypic variation of species and biological communities in the western Amazon (FAPEAM/ CNPq - 003/2009, awarded to Albertina P. Lima).

Currently, studies carried out along the BR-319 and in the Purus-Madeira interfluve have been supported by the following projects:

• Identification of the environmental impacts of the BR-319 highway on fauna in the southwest region of Amazonas: an integrative approach to understand multi-rate patterns (FAPEAM/PROFIX-RH - 009/2021 - 01.02. Junior)

The main objective of this project is to identify whether different biological groups interact with each other and with the environment, and how this happens. Integrating this information will allow identification of critical variables, generating previously unknown hypotheses, and estimating the possible negative impacts of the BR-319 road on the region's fauna. Filling this knowledge gap on a local scale could provide subsidies for national public policies, as has already happened with other studies of ecosystem ecology.

• Long-Term Ecological Research Program in the Southwest of Amazonas, awarded to William Magnusson; funded by the State of Amazonas Research Support Foundation (Public call N 021/2020 – PELD Sudoeste do Amazonas | Grant term: 247/2022)

One of the main objectives of the PELD-PSAM is to understand ecosystem processes, biological interactions, and human impacts on biodiversity in the southwestern Amazon region. However, to achieve this objective, PELD-PSAM needed to consolidate and recover field infrastructure (plots and sampling trails used in the RAPELD system) initially installed in 2006. With that, studies in the region were restarted and several biological groups that were sampled in the last 10 years have been re-sampled , which will allow future attemps to evaluate the effect of the BR-319 highway on the species that live there.

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