*The following is a paper documenting a field project in the rainforest canopy at the Institute for Tropicql Ecology and Conservation in which possible gliding behavior of the Strawberry Poison Dart Frog (*Dendrobates pumilio*) was studied and observed. The project dictates further study in the future and it is hoped that other students will take up where this one left off*

Methods of Exiting Tree Canopies in *Dendrobates pumilio*

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Abstract:

We studied how Dendrobates pumilio frogs exit the canopy. They had been observed jumping and gliding to the ground, and we conjectured that they would have adapted to jump from the canopy to the ground as an energy-saving mechanism. We observed many frogs jumping and gliding from branches to the ground rather than crawling down the trunk, which may be an economic adaptation, but there were not enough quantifiable observations to determine whether the jumping was purposeful or controlled.

Strawberry poison dart frogs (*Dendrobates pumilio*) are a common amphibious species found in neotropical climates, most often in Costa Rica and Panama (Walls 1994). The species has more than six population-specific color morphs (Summers, Symula et al. 1999), all displaying aposematic coloration which deters potential predators (Summers, Cronin et al. 2004). Unlike most frog species, *D. pumilio* spends the tadpole phase of its life cycle in pools of water collected in bromeliads (Walls 1994). Ten to eighteen days after fertilization in leaf litter at the base of a tree, strawberry frog eggs will develop into tadpoles (Walls 1994). After they hatch, either the mother or the father will carry the tadpoles up into bromeliad pools in the tree, where the tadpoles will spend 2-3 months maturing into full-grown frogs (Walls 1994). During this time period, the mother will return to each tadpole/bromeliad once every few days to lay an unfertilized food egg to supply the tadpole with nutrients (Walls 1994).

An enormous amount of energy is allocated for courtship, parental care, and tadpole transport among *D. pumilio* (Young 1979). Because of the intensity and importance of parental tadpole care, a large investment of energy is required for the frogs to ascend and descend trees in travel to and from bromeliads (Young 1979). Descent of rainforest trees by crawling or hopping is a very energy-intensive process for such small organisms, as they have been observed in bromeliads as high as 22.8 m (from my own observations).

There has been anecdotal evidence of poison dart frogs jumping from the canopy and gliding to the ground (Lahanas 2006). Since this would appear to save an enormous amount of energy for frog parents, I hypothesized that frogs would jump from trees to the ground more often than crawling/hopping down on the bark, as an energy-saving mechanism. I also hypothesized that female frogs would be more likely to jump than male frogs, since they have to climb and descend trees more often (males have been observed carrying tadpoles up into bromeliads, but it is the mother who must lay the food eggs into several bromeliad pools to feed her off-

spring over the course of the tadpole phase)(Donnelly 1999).

I collected 32 *D. pumilio* over the course of 5 days, and observed 3 frogs already on a double-trunked primary forest *Prioria copaifera* tree in the vicinity of Boca del Drago, Panama (trunks were 288 and 334 cm in diameter). Sixteen of these frogs were female, 17 were male, and 2 were unidentified by sex. After collecting each morning from an area encompassing a roughly 20 m radius under the tree canopy, I carried the frogs up in a plastic bag to 2 different locations on the tree (I performed the experiment at one location for two of the days, and at the other location for two of the days; the first day was merely an observation day). Half were taken to a wooden plank platform at an elevation of 22.8 m, and the other half were taken to a branch on the larger trunk, 20.82 m high. Once at the location of release, the frogs were allowed out of the plastic bag to move about of their own volition. I observed the behavior of the frogs one at a time, observing until I saw them jump and reach the ground or else until I lost sight of them on the tree trunk. I sexed each frog as I allowed it out of the bag. I recorded the manner in which the frog traveled, its sex, and its behavior as it navigated freely within or out of the canopy. I then quantified the frogs' behavior based on sex, location of release, and method of exiting the tree canopy.

Out of the 32 *D. pumilio* that were carried into the tree, 20 jumped from the canopy to the ground in some way. There was no observable difference between male and female behavior, other than the fact that males seemed to be slightly more reluctant to jump, possibly; females were more likely to jump sooner than males, who tended to observe their options and hop around more before jumping, if they jumped at all. Also, frogs appeared to be more likely to jump from the platform than from the branch. Of the three frogs found on the tree, 1 (male) was observed to jump of his own accord; the other 2 hopped out of sight along the trunk. Furthermore, I observed that frogs tended to jump if they appeared scared or startled. Lastly, I observed that virtually every frog which jumped or fell from the canopy ultimately reached the ground, ricocheting off of the trunk, branches, and leaves as it went down.

My observations yielded no definite conclusions about why frogs tend to jump from trees or crawl down, but the energy-saving hypothesis seems like a very plausible explanation. One may intuitively conjecture that other organisms such as sugar gliders and gliding snakes leap between trees to save energy, as well.

One possible reason more frogs may have tended to jump from the platform as opposed to the branch (where more crawled away), is that the planks were more slippery and a less recognizable environment for the frogs. When released on the branch they seem more likely to have known that they were in a tree, while they may not have been able to tell where they were or how high up they were, from the platform. Furthermore, the platform was composed of slats with space between - this allowed more opportunity for the frogs to jump or fall from the platform, as opposed to the branch (which was solid with rough bark, and attached to the tree in a way familiar to the frogs).

Since I observed the frogs pushing off of objects they hit as they fell, I would assume that they were adapted to reach the ground by falling; if they had not intended to fall, or did not have the ground as their adaptive destination, it seems that they would have been more likely to cling to whatever they landed on first.

The fact that the frogs seemed more likely to jump if they were startled or scared suggests that they may have also adapted the behavior of jumping out of trees in a similar way (and for similar reasons) that gliding snakes and small mammals adapted to glide/fall between trees, rather than climbing all the way down and up another tree when they wish to move or when a predator presents itself. Although poison dart frogs do not have many natural predators, they may occasionally be eaten by naïve birds, snakes, or spiders unaware of the meaning of their aposematic coloration (Donnelly 1999). Moreover, there are certain species adapted to the toxins in their skin, such as the Rufous motmot (which has evolved an anti-toxin in its digestive tract, allowing it to ingest poison dart frogs)(Donnelly 1999). Thus, while predation does not seem to be a huge factor in the life of *D. pumilio*, it may have adapted the jumping behavior as a response to startling or threatening stimuli, as well.

For future studies, I would like to find more frogs naturally in the canopy, and follow their behavior very closely to observe them jumping of their own volition, without any startling. While I observed one frog jumping of its own accord from the canopy, it may have been slightly startled by my presence. I would like to find more evidence of strawberry frogs in their own, unaltered territory, jumping down to the ground after completing their tadpole care.

Several sources of error and complicating factors in my experiment include the fact that the frogs were likely very disoriented, having been carried up into the canopy in a plastic bag and placed in a tree that they may or may not have encountered before. Strawberry frogs are extremely territorial, particularly during breeding season (Gardner 2005), and the confusion of being placed in a bag with other males and females of their own species and carried away from their territory may have altered their behavior.
Furthermore, I have no way of knowing whether the frogs realized that they were in a tree or not, since I carried them up; they may not have good depth perception, and therefore their jumping behavior that I observed may have been merely their normal mode of horizontal transportation, not an intentional/adaptive jumping out of the tree to reach the ground. I could have made it slightly less ambiguous by releasing them all on branches, rather than putting some on the platform.
Another complication was that since I was so high up off the ground, and tied to one side of the tree by climbing ropes, I lost track of several frogs as they moved around the tree and/or fell down. It would be beneficial to work from a perspective closer to the ground, and from a tree with a smaller trunk, so that I could better observe the behavior of each frog from the moment of release to arrival on the ground.
It would be beneficial in future studies to conduct further research on possible controlled gliding behavior in frogs; while most frogs fell straight down, there were several that seemed to jump/glide in a particular direction. This may possibly be related to territoriality; past studies have shown that displaced individuals may orient themselves and return to their original territories (McVey et al. 1981).

Perhaps most importantly, I would hope that a future researcher would be able to film and conclusively document *D. pumilio's* jumping behavior, from bromeliad to branch to ground.

Strawberry poison dart frogs are important to research because while they are fairly common in and around Panama and Costa Rica, their habitat is quickly being destroyed and altered. Amphibians are endangered the world over, and we must learn all we can about them if we are to help these fragile creatures. *D. pumilio* is especially important for conservation and research because the alkaloid toxins in its skin have cardiotonic activity, which may be used in cardiac medicine in the future (Smith 2004).

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