Table 2 Hypotheses, treatments, and results of D. pumilio experiment conducted at La Selva, Costa Rica 10-12 February, 1991.

Hypothesis	Treatment	Result
Response to auditory cues > chemical cues > visual cues	auditory response vs. chemical response	auditory > chemical U_s=33, n_1=8, n_2=5, p<0.05
	auditory response vs. visual response	auditory > visual U_s=35.5, n_1=8, n_2=5, p<0.05
	chemical response vs. visual response	chemical = visual U_s=14.5, n_1=5, n_2=5, p>0.05
	auditory response vs. control response	auditory > control U_s=24, n_1=8, n_2=3, p< 0.05
	visual response vs. control response	visual = control U_s=7, n_1=5, n_2=2, p>0.05
Response to stimulus increases as distance from stimulus decreases	auditory response vs. distance	r=-0.157, r^2=0.025, n=29, p>0.05
	chemical response vs. distance	r=-0.207,r^2=0.043, n=17, p>0.05
	visual response vs. distance	r=-0.310, r^2=0.096, n=14, p>0.05
Response to conspecific individuals > response to heterospecific individuals	D. pumilio vs. two other species	D. pumilio > two other species U_s=24, n_1=6, n_2=4, p<0.05
Response to foreign males > response to familiar males	foreign response vs. familiar response	foreign > familiar U=33, n_1=6, n_2=6, p<0.05

Literature Cited

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THE EFFECT OF BROMELIADS AND LEAF LITTER ON DENDROBATES PUMILIO DISTRIBUTION

Christy Goodale and Geoff Kunz

Abstract (G.K.)

We observed that an abandoned cacao plantation at La Selva supported a much denser Dendrobates pumilio population than the surrounding natural forest. We also noted that the cacao grove produced a very thick litter layer, an important resource for food and shelter, and contained a high density of bromeliads, a potentially limiting reproductive resource. We investigated the importance of these two physical factors in influencing D. pumilio distribution on natural and litter-reduced plots and in areas of high and low bromeliad density. Although both factors appeared to influence distribution, the presence of litter was significantly more important in determining the presence of frogs. We concluded that it is probably the thicker litter layer in the cacao grove that supports the dense D. pumilio population.

Introduction (C.G.)

Dendrobates pumilio or poison dart frogs occur throughout the La Selva Biological Reserve, Costa Rica; however, they are extremely common in the abandoned cacao plantation, now known as the Las Vegas Annex of La Selva. We wanted to examine factors which influence D. pumilio density, to try to explain the high frog density within the cacao plantation. The two variables we examined were litter abundance and bromeliad availability. Litter may be important as a cool, moist, protected habitat for the frogs, and as a source of ants and termites, the primary food for D. pumilio. We were unable to directly test the effect of prey availability on frog density, due to rain which interfered with our insect density sampling technique. Both litter and bromeliads are important reproductive resources: oviposition occurs in the leaf litter, and tadpoles are reared in water-filled bromeliads (Crump, 1983). D. pumilio are territorial and bromeliads have been shown to be the object of male defense (Donnelly, 1989).

By determining how these variables affect D. pumilio density, we hoped to partly explain, and ultimately to predict D. pumilio distribution within the tropical lowland rainforest.

Methods (G.K.)

We conducted our study in an abandoned cacao plantation in the Las Vegas Annex of La Selva Biological Station, Costa Rica. We censused the D. pumilio populations in sixteen 5m x 5m experimental plots. These plots were divided into 4 treatments of 4 replicates each: (1) high bromeliads with high litter, (2) high bromeliads with low litter, (3) low bromeliads with high litter, and (4) low bromeliads with low litter.

Bromeliads were fairly abundant in the cacao trees but were unevenly distributed, creating naturally occurring areas of high and low density. The litter cover was fairly constant throughout the grove. It consisted of a heavy layer of large, dry cacao leaves with a thin layer of moist decaying leaf matter underneath. The grove had recently been cleared of all low-lying vegetation, and several plots included a moist, rotting pile of banana fronds and a clump of stumps from which they were cut.

We scouted the grove looking for different bromeliad densities. We established 8 plots in areas of high density (9-35 bromeliads/plot) and 8 plots in areas of low density (0-2 bromeliads/plot). A bromeliad was considered to be within a plot if the trunk of the tree in which it was located was within the plot's perimeter. Each plot contained several similarly sized trees. We removed most of the litter from 4 of the plots in each group to create a low litter situation. We shuffled through the high litter plots to simulate the disturbance imposed on the removal plots.

We censused each plot approximately 24 hours after marking and disturbing it to allow time for the re-entry of displaced frogs. We first cleared a 0.3-0.6m perimeter in the litter around the plot to make it easier to see fleeing frogs. We then worked through the plot from the outside in, sifting through the litter by hand. We captured each frog in the plot to avoid recounting and recorded the total number of frogs per plot.

Results (C.G.)

A Kruskal-Wallis test indicates that there was a significant difference among the four treatments in the number of D. pumilio caught ($K = 4$, $H = 8.164$, $p < 0.05$). Actual numbers of frogs caught are recorded in Table 1.

Significantly more frogs were captured on high litter plots than on low litter plots, for plots under both low bromeliad treatments ($N = 4$, $t = 5.11$, $p < 0.01$) and under high bromeliad treatments ($n = 4$, $t = 3.54$, $p < 0.05$). More frogs were caught on high litter, high bromeliad density plots than on low litter, low bromeliad density plots ($n = 4$, $t = 5.97$, $p < 0.01$).

There was no statistical difference in the number of frogs caught due to different bromeliad levels, for either the high litter or low litter treatments.

Discussion (G.K., C.G.)

Litter abundance appears to be the more important factor influencing D. pumilio distribution. Regardless of bromeliad density, there were significantly more frogs on plots with heavy litter. The thick cacao litter provides a potentially rich foraging environment and a consistently cool, moist habitat. We were unable to tell which of these two litter resources was more important; a successful insect census for each treatment plot may have indicated the relative importance of prey abundance on D. pumilio distribution. The overall environment provided by the litter seems to be vital to the frogs. We found no frogs on the barren ground, the few frogs present in the litter removal plots were located in small remaining pockets of litter. Exceptionally high densities were found in the particularly gooey, moist habitat offered by the piles of decaying banana slash.

Frog density was not significantly influenced by bromeliad density, but we noticed a distinct trend: we found an average of 3.5 more frogs on the high bromeliad plots than on the low. We found many frogs at the bases of trees, but it is uncertain whether these were males guarding bromeliads in the trees, or whether the frogs were simply seeking cover.

Bromeliads may be important for reproductive and territorial values, but the food and habitat offered litter appears to be the more significant variable in determining D. pumilio distribution. The litter in the cacao plantation appears to be much thicker than that in the primary forest; this may partly explain the high D. pumilio density in the plantation.

Table 1 Number of D. pumilio per 5mx5m plot in the abandoned Las Vegas cacao plantation, La Selva, Costa Rica, February 11-12, 1991.

	Litter Retained		Litter Removed	
Bromeliad Density Low(0-2/plot)	12 15 9 7	x=10.75 s^2=12.25	1 3 0 1	x=1.25 s^2=1.58
Bromeliad Density High(9-35/plot)	15 8 16 17	x=14.00 s^2=16.67	0 1 9 5	x=3.75 s^2=16.90

Literature Cited

Crump, M.L. 1983. Dendrobates granuliferus and Dendrobates pumilio (Ranita Roja, Rana Veneriosa, Poison Dart Frogs): from Costa Rican Natural History. Daniel H. Janzen, Editor. Chicago: University of Chicago Press. p. 396-398.

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