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Cover photographs. Front: *Tillandsia viridiflora* (Beer) Baker ranges from Mexico to Nicaragua. It has relatively large, spidery-like flowers that when faded, tend to hang down like tassels. Before it reaches maturity, the plant sends out numerous plantlets that are easy to detach and grow separately. A variegated form is also available but the variegation is unstable in offsets. Photograph by Marcel Lecoufle. **Back:** *Tillandsia flabellate* from Mexico, Guatemala and El Salvador. Photograph by Marcel Lecoufle.

CONTENTS

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Water Pollution in Bromeliad Tanks - An Experimental Approach

James Burgess[1], Edward Burgess[2], Margaret Lowman[3], and Saul Lowitt[4]

Bromeliads are important epiphytes in many ecosystems including Florida hammocks, sub-tropical and tropical rain forests, and cloud forests (Benzing 1990). Many epiphytic bromeliads form a rosette structure that holds a tank of water that comprises a mini-ecosystem in the forest canopy. These aquatic ecosystems house many economically important insects (e.g. Diptera, Coleoptera) as well as other organisms, most of which are very poorly studied. Bromeliad tanks have been reported to contain ants, beetles, mosquitoes, spiders, millipedes, centipedes, slugs, snails, frogs, salamanders, lizards, snakes, birds' nests, rats, mice, and opossums (Neill 1951). Some organisms are visitors and some are residents.

Due to the logistic difficulties of accessing tropical canopies, many bromeliad tanks have never been examined or surveyed (Lowman and Nadkarni 1995; Lowman 1999). In addition to the difficulties of access to epiphytes in tree canopies, bromeliad tank ecosystems are doubly difficult to survey because the removal of the aquatic water medium may lead to mortality of the plant. It is almost impossible to extract the organisms and water from a bromeliad without physically removing the plant from its phorophyte and turning it upside down. Such destructive harvesting of bromeliads in a rain forest canopy could lead to the depletion of localized bromeliad populations, and is not advised. An experimental design that involved the creation of artificial bromeliads was used, since containers that simulate tanks have been utilized in other phytotelm studies (e.g. Frank 1986).

The impact of air and water pollution on bromeliads has been suggested (Benzing and Bermudes 1991), and consequently the affects of such airborne contaminants may also affect the health of the tank ecosystems as well as the host plants. Common types of water pollution in Florida include salinity, acid rain, detergents, fertilizers, herbicides and insecticides. Such airborne contaminants most likely drift even to the most remote tropical rain forest canopies as well.

This research project tested the effects of different types of water pollution on bromeliad tank ecosystems in Florida. In addition, we developed an artificial bromeliad for our experimental design that can be replicated for many different situations where students, classrooms, or scientists need to set up studies on

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phytotelms (i.e. aquatic habitats such as tank bromeliads, tree holes, or leaf pockets in *Heliconia* and others) (Macguire 1971). Recently, the Jason Project for Education used our artificial bromeliad design to examine the diversity of organisms in artificial bromeliad tanks between tropical and temperate latitudes (Lowman 1998).

METHODS

Forty-five cups (12 ounce, green opaque plastic) were labeled and filled with 125 ml of bottled water (pH = 7.0). Five pollution treatments were compared: 1. salt water (as when salt spray infiltrates bromeliads along coastal Florida); 2. fertilizer (Miracle-gro added to the water tanks); 3. detergents (liquid soaps added to water tanks); 4. acid rain (vinegar added to water as a mild form of acid rain); and 5. control which comprised water alone in the tank. The cups were placed in the canopy of a live oak (*Quercus virginiana*) at a height of 6 meters that is representative of the canopy height in Florida hammocks.

Approximately three cups of each treatment were harvested after 2 weeks, 4 weeks, and 6 weeks, so that we could observe what organisms settled into the bromeliad tanks over time as well as how the pollutants affected both the abundance and the diversity of the tank inhabitants. When the cups were harvested, their contents were poured into a bowl, and observed under a microscope. Each cup was tallied separately, and the three replicates averaged for each harvest. Our hypothesis was that the pollution of the bromeliad tanks would result in a decrease in diversity of organisms residing there.

RESULTS

The abundance of arthropods in artificial bromeliad tanks ranged from a high of thirty-seven individuals to a low of zero. Insects per cup averaged 5.66 individuals. Averages per treatment were (from highest to lowest): detergent 9.11; control 6.56; acid rain 5.44; fertilizer 3.67; salt 3.5. Statistical analyses showed that there was no significant difference between the treatments (ANOVA, $F=2.11$), but there was significant difference over time ($F=4.09$).

In terms of diversity, the highest number of species ($N=11$) was recorded in a cup with detergent treatment. In decreasing order, the average diversity was detergent, acid, fertilizer, salt, and control. Although the control had relatively low diversity, it did however have the highest number of live specimens. This suggests that pure water may be the most successful to maintain a healthy ecosystem over time, whereas the pollutants initially attracted insects which then died in the contaminants. We need to extend this experiment over a longer time period to test this.

Our hypothesis was not upheld, since the controls did not have the highest abundance and diversity of organisms. This may be due to the time-scale of the experiment. Over such a short time (6 weeks) the artificial bromeliads may have

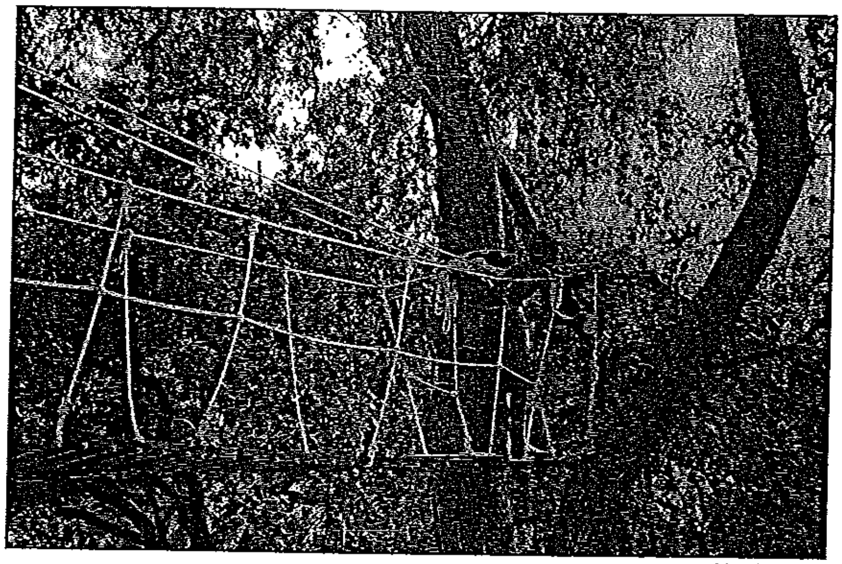

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Figure 7. Using a canopy walkway in live oaks to set up artificial bromeliad tanks for the experiment.

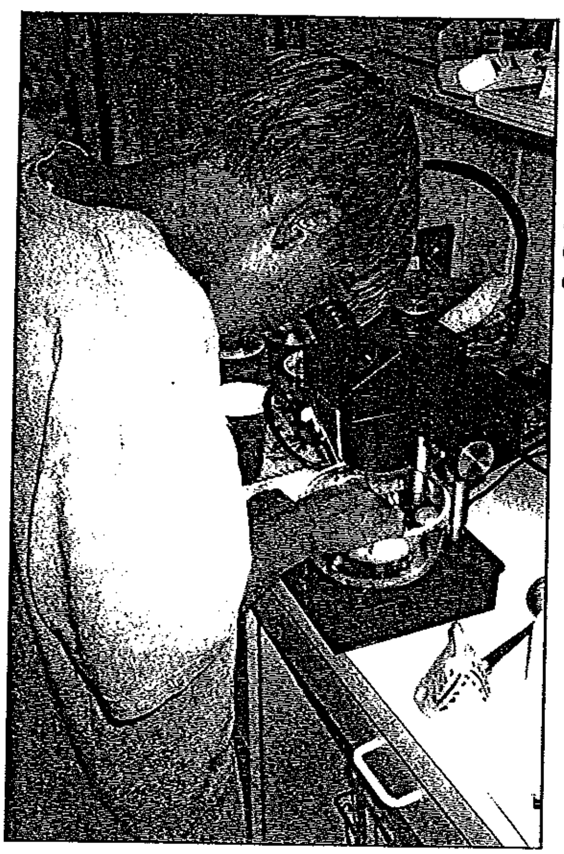

Figure 8. Identifying the contents of bromeliads tanks with a dissecting microscope.

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Bromeliad Tanks

	Time 1		Time 2		Time 3		
Control							
0-1	**12**	0-4	**0**	0-7	**13**		
0-2	**4**	0-5	**0**	0-8	**7**		
0-3	**22**	0-6	**x**	0-9	**1**		
Total	**38**	+	**0**	+	**21**	=	***59***
Average	**12.67**		**0.00**		**7.00**		
Salt							
1-1	**6**	1-4	**5**	1-7	**2**		
1-2	**5**	1-5	**x**	1-8	**1**		
1-3	**5**	1-6	**2**	1-9	**2**		
Total	**16**	+	**7**	+	**5**	=	***28***
Average	**5.33**		**3.50**		**1.67**		
Fertilizer							
2-1	**5**	2-4	**3**	2-7	**2**		
2-2	**4**	2-5	**5**	2-8	**5**		
2-3	**2**	2-6	**6**	2-9	**1**		
Total	**11**	+	**14**	+	**8**	=	***33***
Average	**3.67**		**4.67**		**2.67**		
Detergents							
3-1	**4**	3-4	**1**	3-7	**37**		
3-2	**4**	3-5	**8**	3-8	**8**		
3-3	**6**	3-6	**5**	3-9	**9**		
Total	**14**	+	**14**	+	**54**	=	***82***
Average	**4.67**		**4.67**		**18.00**		
Acid							
4-1	**6**	4-4	**4**	4-7	**4**		
4-2	**6**	4-5	**5**	4-8	**14**		
4-3	**9**	4-6	**0**	4-9	**1**		
Total	**21**	+	**9**	+	**19**	=	***49***
Average	**7.00**		**3.00**		**6.33**		
Col. Total	**100**		**44**		**107**	=	***251***
Col. Avg.	**6.67**		**3.17**		**7.13**	=	***16.97***

attracted visitors but not resident insects. The fact that only the control housed live insects suggests that this may be the case, and that the pollutants attracted insects via smell that only ended up falling to their deaths in the polluted cups.

Seasonality may also have affected our results. The abundance of organisms may be lower due to the fact that this experiment was conducted during autumn and winter. We hope to repeat this experiment during spring and summer, and possibly over a longer time period.

Bromeliad tanks represent important centers of biodiversity in forests, and they have not been adequately studied. It is likely that airborne pollutants will play a major role in the health of bromeliad tank ecosystems, and we advocate further studies on these ecological interactions.

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