energy return from forage falls, activity should decline. *Haemelia* flowers may not provide nectar of the same quality or quantity during excessively wet periods. On average, a hummingbird like the rufous-tail expends 18 calories per minute while hovering (Baker 1983). Nectar production may be so low during extended rainy periods that the energy required to fly is not returned by the energy gained from consuming the nectar.

While rufous-tailed hummingbird activity was reduced during the overall rainy day, visits to Haemelia trees by smaller non-territorial hummingbirds increased. Perhaps these opportunistic birds rely on rainy conditions to increase their nectar uptake when the chances of being chased off are reduced. Given the relatively high surface to volume ratio of these smaller birds, it is likely that these birds are less well insulated than larger birds. Therefore, while the rufous-tailed hummingbird can afford to remain inactive when flying is not energetically favorable, smaller birds may be forced to fly in order to maintain a stable body temperature during extended rainy periods. Also, if the wing area of smaller birds is proportionately smaller, the cooling effects of flying may be outweighed by the warming of metabolizing. And it is more likely that the small birds will have energy to metabolize because they are less likely to be driven off during the rain. Thus, small non-territorial birds counteract the energy demands of flying with energy from a more accessible source.

Interestingly, rufous-tails spent more time flying during the infrequent periods of rain on the overall dry day than during the dry periods of the same day. This seems to be consistent with the above analysis. Perhaps the smaller birds, being more susceptible to cooling during rainy periods, must be active even during these short periods of rain. If they remain active by foraging in rufous-tail territories, then it is likely that the rufous-tail must increase its activity to defend against these intrusions. Perhaps the brief mists do not pose such a cooling threat to the larger bird when flying. Quantification of rain intensity, duration, and temperature would improve this analysis. Future studies should focus more closely on the consequences of rain on the relative success of territorial and non-territorial birds. To do this accurately, the effects of bird size on metabolic requirements must be separated from the effects of territoriality on defense and foraging behavior.

## Literature Cited

Baker, H.G., K.S. Bawa, G.W. Frankie and P.A. Opler. 1983. Reproductive biology of plants in tropical forests. Pages 183-201 *in* F.B. Golley, editor. Ecosystems of the world. Vol. 14A, Tropical rain forest ecosystems. Elsevier Scientific Press, Amsterdam.





# CREATING CONTOUR MAPS OF THE FEBRUARY FLOOD AT LA SELVA BIOLOGICAL RESEARCH STATION

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*Abstract.* On 13-15 February, 1996, La Selva Biological Research Station experienced its largest flood since 1970. Due to the potential ecological impact on the La Selva rainforest, we produced five GIS floodline maps to detail the recession of the flood from its high water mark. These maps will provide a tool for researchers when evaluating the impact of this disturbance on the La Selva's ecosystem.

*Key words: disturbance, flood, GIS mapping system, La Selva*

## Introduction

La Selva Biological Research Station, Costa Rica, is located within a tropical rainforest. On 13-15 February, 1996, La Selva experienced the largest flood since 1970, receiving 306 mm of precipitation in 3 days. Frequent disturbances such as tree falls and tropical storms have been well studied at La Selva, but little is known about how rare disturbances, such as large floods, might influence forest ecology.

In order to study the short and long-term effects of this environmental disturbance, detailed records of flood coverage are necessary. We produced a time-series of Geographic Information System (GIS) maps tracking the level of the flood as it receded from its high water mark.

## Methods

To determine the extent of flooding at La Selva, we measured the water level at a number of designated locations as the flood receded. Five groups of two people each were sent to the most frequently researched areas of La Selva to record water levels along the trails. Distance from the water level on the trail to the nearest GIS grid pole or trail marker was measured. Both sides of a flooded area were recorded. The highest point of the flood was reached at ≈1600 on 13 February. High water lines were marked by various La Selva residents and measured later. Groups took readings as the water level declined on 14 February, 1996 at 0930, 1500 and 1600, and on 15 February at 0830. We concentrated on seven focal flood areas: the successional plots, the Sendero Oriental (SOR), two sites along the Sendero Tres Rios (STR) (one at the far end near the Camino Experimental Sur (CES) and one between STR 150-1000), the Camino Cantarrana (CCA), Sendero Surá (SUR), Camino Circular Cercano (CCC), and the Camino Circular Lejano (CCL). River levels were also measured at regular intervals during the flood from the Puente Sura and the main footbridge on the Puerto Viejo.

Floodline maps were created on Arc and Arcview using La Selva's GIS trail and grid system, and topographical map. Flood line measurements were plotted onto the GIS trail map, and then overlayed with an elevational topographical map of La Selva. Contour lines were named on either side of the data points, determining the average elevation of the flood at each time period. These data were extrapolated to map flood coverage, and subsequent water recession, over the entire La Selva area.

## Results

Recorded high water levels from 13 February fell cosistently between 39 and 41 m asl on the existing contour map of La Selva. Figure 1 shows the predicted high water marks and path of recession of flood waters between February 13-15. The high degree of flooding along the streams, primarily the Surá Creek, is a result of water backing up from the flooded Rio Puerto Viejo. The secondary forest area surrounding the STR received the greatest degree of direct flooding from the river due to it's low elevation. The research labs, marked with an X, were untouched by flood waters.

## Discussion

The flood maps provide an approximate account of water levels at different stages of flood recession. The variation in high water marks between 39 and 41 m

asl indicates high resolution of existing topographical maps and suggests that field measurements were accurate. Nevertheless, the topographical map has an actual resolution of 5 m and an extrapolated resolution of 1 m. Even small errors within this range may have underestimated or overestimated the total submerged area.

The 1996 flood map may be used as a reference for future studies. To understand the effects of past floods on soil composition, data from the 1996 flood can be overlain on existing maps of alluvial soil coverage. There may be vegetational gradients that can be explained by soil deposition from large scale flooding events. Additionally, flood maps may provide background to future studies comparing treefall frequency, invertebrate abundance, and invertebrate recolonization in submerged areas. The flood maps also provide us with accurate information on the amount of time that certain areas were submerged. From these data, future studies can examine the resiliency of various ecosystems or communities within La Selva based on the degree to which they were affected by the flood, and the amount of time it takes them to return to pre-disturbance equilibrium abundances.

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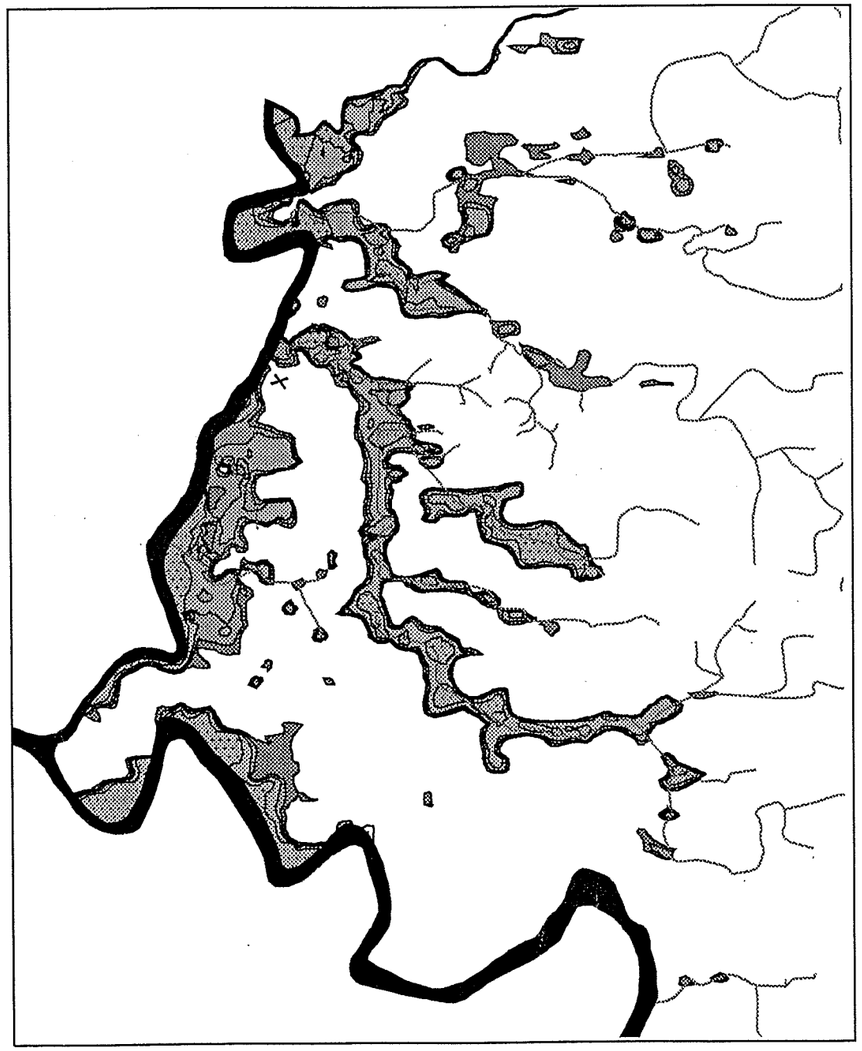


La Selva Flood, February, 1996