EFFECTS OF THE 1997-98 EL NIÑO EVENT ON THE VEGETATION OF ALCEDO VOLCANO, ISABELA ISLAND

Iván Aldaz and Alan Tye

INTRODUCTION

On the majority of the islands, islets, and even rocks that form the Galápagos Archipelago, El Niño caused changes in the native plant communities of Galápagos (see also article by A. Tye and I. Aldaz in this issue). In this article, we discuss the effects produced by the intense and constant rainfall on the vegetation of Alcedo Volcano, Isabela Island, by means of studies carried out before and after El Niño.

METHODS

Alcedo is one of the five active volcanoes comprising Isabela Island. At present it is a site with enormous ecological problems caused primarily by goats (*Capra hircus*), whose numbers were estimated before El Niño to be between 75,000 and 100,000 (Cayot 1997). In November 1995, a vegetation monitoring system was begun on Alcedo, whose objective is to evaluate the recovery of the vegetation during campaigns to eradicate introduced animals. Fourteen quadrats of 900 m^2 were established in the area of greatest impact, that is, on the southern portion of the volcano. In addition, one year later, four quadrats of 400 m^2 were set up to monitor the status of *Darwiniothamnus tenuifolius* and *Scalesia microcephala* (Figure 1). Monitoring was carried every six months, alternating between the garúa season (light mists, from May to October) and the season with intense rainfall, from November to April. Basically, the monitoring consists of making a floristic inventory, measuring the plant cover, and measuring the diameter at breast-height (DBH) of trees and bushes. The last variable is usually measured every 12 months. More details on methodology of vegetation monitoring can be found in the monitoring manual of Mauchamp (1996).

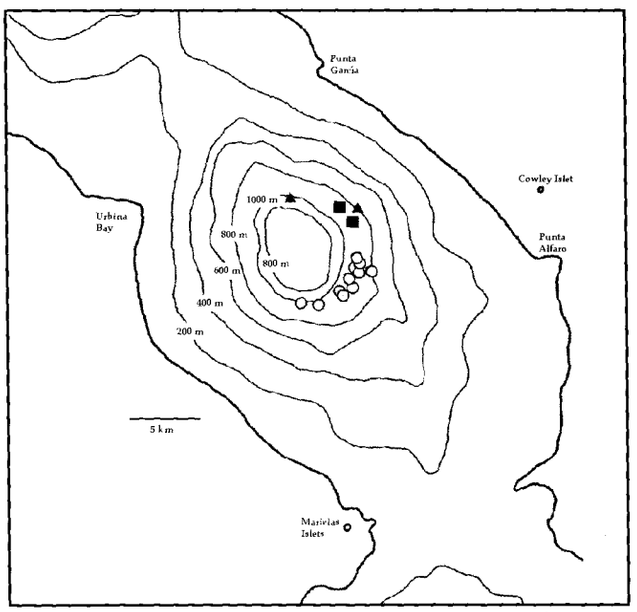

Figure 1. Map of Alcedo Volcano, Isabela Island, showing vegetation monitoring quadrats. Circles indicate the areas of the 14 permanent quadrats for vegetation monitoring; squares indicate the quadrats for the study of Darwiniothamnus tenuifolius*; and triangles indicate the quadrats for the study of* Scalesia microcephala.

RESULTS

The results from the monitoring program allow an evaluation of the effects of El Niño on the vegetation of Alcedo Volcano, comparing the data obtained before the phenomenon (monitoring between November 1995 and June 1997), during El Niño (monitoring in November 1997 and April 1998), and after it (monitoring in October 1998). In this article we present a preliminary analysis that gives a general idea of the changes in the floristic composition on Alcedo during El Niño. The precipitation data are only indicative, since the measurements are from the meteorological station at the Charles Darwin Research Station on Santa Cruz Island. It should be mentioned that the quantity of millimeters of rain is that which accumulated between each date. A fuller analysis will be published following the acquisition of additional data from the vegetation monitoring on Alcedo Volcano.

Floristic inventory

Figure 2 indicates the changes in the total number of species per monitoring trip in the fourteen quadrats of 900 m^2, related to the precipitation at the Darwin Station. During the first monitoring, undertaken in November 1995 (garúa season), 32 species were recorded; the rainfall was minimal. In the second monitoring survey in May 1996 (rainy season), annual species appeared, giving a total of 57 species recorded. During the third monitoring, undertaken in a new period of garúa, the number of species dropped to 50, possibly because it had stopped raining. In June 1997, there was heavy rainfall, which diminished in the months of September and November. Nevertheless, the number

of species recorded remained high in November. The highest peak in rainfall was in April 1998, when the greatest number of species, 102, was recorded. Six months later, this declined to 86 species, probably due to the dry season then prevailing in the islands.

In other sites, uncommon species were found, such as *Phytolacca octandra* (native), *Jaltomata werfii* (native), and *Pleuropetalum darwinii* (endemic).

Variations in the native vegetation due to rainfall

The majority of plants on Alcedo are abundant during the rainy season. A case in point is *Ipomoea alba*, which was not found in any of the regular monitoring quadrats until June 1997, but, during the winter and with the appearance of El Niño, it recovered remarkably, forming very dense patches. In the last monitoring, carried out in October 1998, the vegetation in general had suffered serious modifications, particularly *I. alba*, due to the drought and the continuing destructive action of the goats. In addition, the percentage cover of *Paspalum conjugatum* increased enormously during the rainy season, probably because it is a grass resistant to competition from other herbs.

In general terms, the vegetative cover was high during the 1997-98 El Niño. Apart from *I. alba*, the dominant and common species that covered the soil in the humid zone (south) of the volcano during El Niño were the following: *Borreria laevis, Cyperus brevifolius, Dichondra repens, Pteridium aquilinum, Cuphea carthagenensis, Plantago major, Hyptis rhomboidea, Physalis pubescens, Elaterium carthagenense,* and *Sida rhombifolia.* Figure 3 shows the variability in vegetative cover and includes the species that are considered most frequent and, at the same time, the most abundant, during the monitoring on Alcedo.

Appearance and dispersion of introduced species

El Niño may have favored the appearance of some introduced species, such as *Ricinus communis.* About ten adult plants of 3 m height were found, along with a good number of subadults and seedlings. The plant had previously been recorded at the site and it is likely that dormant seed had remained in the soil until helped to germinate by Niño rainfall. The area of dispersion of this introduced plant was just on the slopes of the south-eastern side of the volcano (200 m north of vegetation monitoring quadrat No. 12). The individuals of this species were eliminated immediately and the seeds collected and burned. Other introduced species that appeared, in order of dominance, are *Sida rhombifolia, Hyptis rhomboidea, Plantago major, Synedrella nodiflora, Eleusine indica, Cuphea carthagenensis, Sonchus oleraceus, Stachytarpheta cayennensis, Canna lutea,* and *Datura stramonium.* The most aggressive species, given their dispersal and invasion of large areas, their displacement of native herb species, and the possible impediment to the natural regeneration of *Scalesia microcephala, Darwiniothamnus tenuifolius, Tournefortia rufo-sericea, Zanthoxylum fagara,* and *Cordia leucophlyctis,* are for the most part *S. rhombifolia* and, to a lesser extent, *H. rhomboidea.*

Growth in diameter of marked trees and bushes

The measurement of diameter at breast height (DBH) of trees and bushes within the vegetation monitoring quadrats began in May 1996, with the marking of 438 individuals of the following species: *Scalesia micro-*

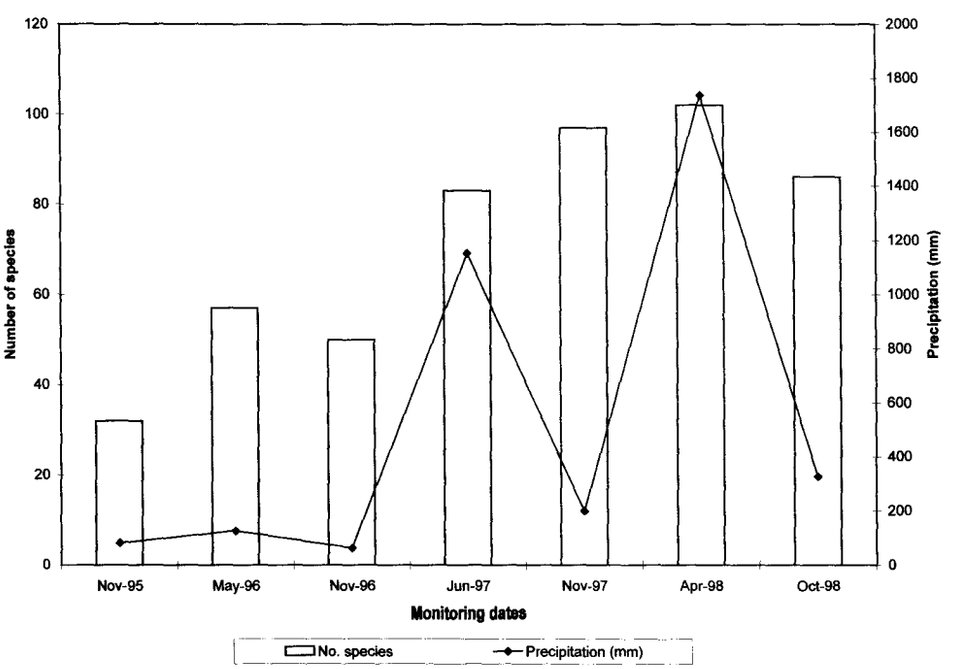

Figure 2. Changes in the total number of plant species in relation to climatic changes during monitoring of quadrats on Alcedo Volcano. Data on precipitation provided by the meteorological station, CDRS. Accumulated precipitation during each period of the study.

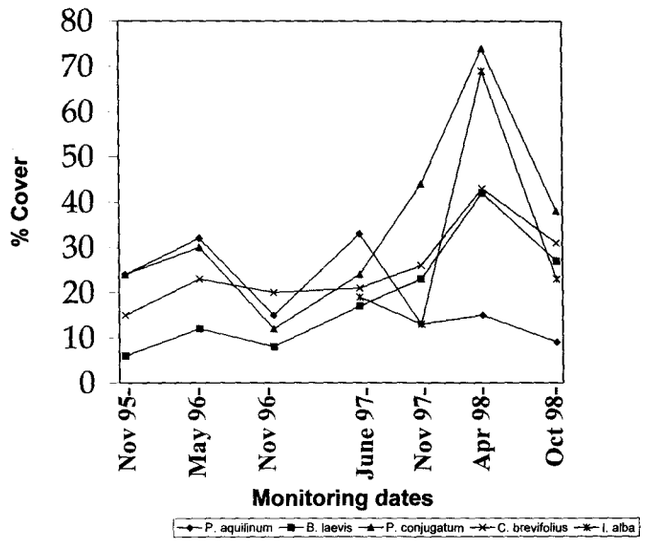

Figure 3. Variations in cover by predominant species during the vegetation monitoring on Alcedo.

cephala, Tournefortia rufo-sericea, Zanthoxylum fagara, Croton scouleri, Psidium galapageium, Cordia leucophlyctis, and *Iochroma ellipticum.* The largest diameters were those of *Zanthoxylum, Scalesia,* and *Tournefortia,* which varied between 20 and 25 cm. The growth of DBH during the first year, May 1996 to June 1997, is slightly less than that which occurred in the second year, June 1997 to October 1998 (Figure 4).

Mortality of marked trees and bushes

During the first year of the monitoring project, the greatest decrease in the number of individuals was in *P. galapageium, C. leucophlyctis, T. rufo-sericea,* and *S. microcephala.* During the second year, there was a greater percentage of trees and bushes that died, with the species affected being the same as during the first year, as well as *C. scouleri* on this occasion (Figure 5). Evidently, the high rainfall, combined with the steep slopes, caused many of the trees to fall and consequently die. The population of *Darwiniothamnus tenuifolius* suffered a great decrease; in 1996 about 150 plants of this species were recorded in the quadrats established for its study, while in 1997 only 21 were found, and in 1998 the number dropped to 12. Possible causes of death of the plants were the excessive rainfall, consumption by goats, and the invasion of *S. rhombifolia,* an introduced plant that currently seems to be impeding the regeneration of *Darwiniothamnus.* The regeneration of tree and bush species in the humid forest zone increased after winter and El Niño, particularly *T. rufo-sericea, S. microcephala, C. scouleri, Solanum erianthum,* and *Psychotria rufipes.*

DISCUSSION

According to the monitoring that has been conducted to date on Alcedo Volcano, we can state that the number of plant species varies markedly in relation to the intensity of rainfall, with the number of species being greater during El Niño. According to the reference rainfall data, the rainfall decreased progressively from June until November 1997, with light rains, which allowed the number of species to continue increasing. However, from April to October 1998, there was an abrupt change in the weather; heavy rains lasted until May, after which there was a period of drought. This is the most probable reason that fewer species were found in the monitoring of October 1998. On the other hand, it is possible that this variation is related to the campaigns to eradicate introduced mammals. Hamann (1985) and Luong (1985) indicate that there was an increase in species, particularly herbaceous ones, during El Niño, followed by a decline in the number of species during the subsequent "La Niña" drought. This pattern seems to be occuring the current El Niño-La Niña cycle on Alcedo.

One of the species on Alcedo whose increase depended on the rainy or very rainy season is *I. alba.* Van der Werff (1978, 1985) and Hamann (1981) indicate the presence of this species, forming a dense mat over trees and bushes. During the 1982-83 El Niño, this climbing species covered extensive areas in the south-east, east, and northeast inside and outside the crater of Alcedo, forming impenetrable thickets of vegetation (C. Márquez, pers. comm.). Subsequently, the population of *I. alba* decreased due to the lack of rainfall and, above all, consumption by goats (Freire 1992). In April 1998, this climbing plant was dominant and we observed extensive patches on the rim of the volcano, the upper slopes, and the lower slopes, but in October of the same year, it was uncommon to find these dense patches.

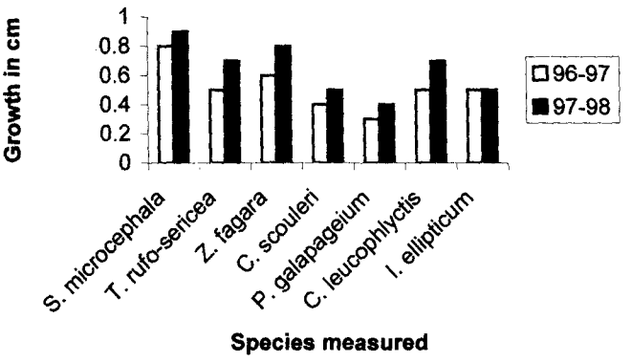

Figure 4. Average annual growth of DBH of marked trees and bushes alive until October 1998.

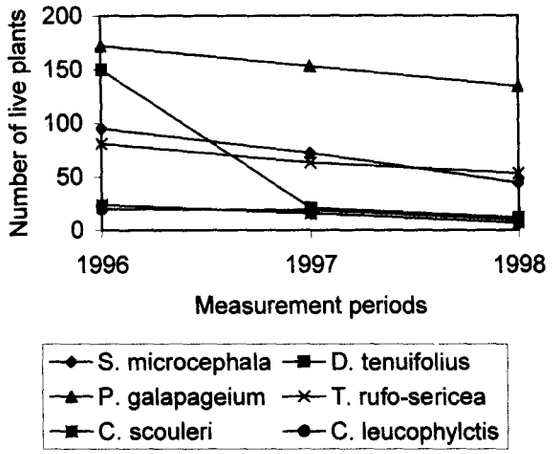

Figure 5. Annual decrease in the number of plants for the measurement of DBH and Darwiniothamnus tenuifolius, until October 1998.

Nevertheless, it may recuperate with the next rains. On the other hand, figure 3 shows the decrease in the percentage cover of *P. aquilinum*, perhaps due to the competition that occurred just when *I. alba* was recorded for the first time, in the monitoring of June 1997. *I. alba* totally covered *P. aquilinum*, impeding its regeneration and survival. In the last months of 1998, it was observed that the soil had been eroded by the rains and the presence of introduced mammals, which has given rise to areas devoid of vegetation.

Ricinus communis is considered invasive in the Galápagos Archipelago. It disperses rapidly in the rainy season. Van der Werff found some plants on Alcedo in 1978; subsequently they were eliminated by the Galápagos National Park Service, but possibly some seeds remained that germinated in 1998. Once again this species has been eliminated and the seeds burned. Nevertheless it is advisable to frequently visit the area where this plant was most recently found. Other introduced species that have expanded rapidly throughout Alcedo are *S. rhombifolia* and *H. rhomboidea*. These species were recorded by van der Werff (1978), Hamann (1981), Lawesson (1987), and Freire (1992). According to the vegetation monitoring, *S. rhombifolia* was first found in May 1996, while *H. rhomboidea* was found in June 1997. During the last monitoring, in October 1998, we observed that *S. rhombifolia* had become a potentially damaging species, with individuals up to 2.5 m high. Apparently this species decreases during periods of drought, but it has a great number of seeds that remain dormant in the soil, awaiting a period of rain to reappear with vigor.

The forest benefitted from the quantity of rainfall and showed an excellent natural regeneration of bushy and tree species during El Niño. The opposite occurred with adult trees and bushes that grow on the fragile soil and the middle slope of the volcano. These were at greater risk of dying due to the erosion caused by the formation of rivulets and gullies. With respect to the slight increase in DBH in trees and bushes alive during 1998, it seems that there exists a direct influence from the rains; this should become clearer following further monitoring periods.

ACKNOWLEDGMENTS

We would like to express a special thanks to the following people of the CDRS, who have contributed information and comments prior to the publication of this article: Mark Gardener, Cruz Márquez, Solanda Rea, Marco Altimirano, Eduardo Espinoza, Paola Buitrón, Wacho Llerena, Heidi Snell, and Kristin Bergeson. We would like to thank Howard Snell for help with the design of the maps. We would also like to thank Sol Rojas for checking the Spanish version of this article and to Gayle Davis-Merlen for help with translating it to English.

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Iván Aldaz, Charles Darwin Research Station, Galápagos, Ecuador (e-mail: ivan@fcdarwin.org.ec). Alan Tye, Charles Darwin Research Station, Galápagos, Ecuador (e-mail: atye@fcdarwin.org.ec).