EFFECTS OF THE FERAL GOAT POPULATION EXPLOSION ON
ALCEDO VOLCANO (ISABELA, GALAPAGOS) BETWEEN 1986 AND 1996

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SUMMARY

During the first week of April 1986, before the overwhelming presence of goats, we sampled terrestrial macroinvertebrates on Alcedo Volcano along an altitudinal transect from the seashore to the top. Vegetation composition and structure at all sampling sites were described and photographs were taken. In 1996, when the Alcedo feral goat population had exploded to an estimated 50,000 to 100,000 and before large scale goat control began, the same transect was resampled and redocumented. In this contribution, site descriptions are summarized, compared between 1986 and 1996 and illustrated with a series of photographs.

RESUMEN

Efectos de la explosión de la población feral de cabras en el Volcán Alcedo (Isabela,Galápagos) entre 1986 y 1996. Durante la primera semana de abril de 1986, antes de la abrumadora presencia de cabras, muestreamos los macroinvertebrados terrestres en el Volcán Alcedo a lo largo de un transecto altitudinal desde la costa marina hasta la cima. La composición y estructura de la vegetación en todos los sitios de muestreo fueron descritos y fotografiados. En 1996, cuando la población feral de cabras de Alcedo había repuntado hasta un estimado de 50,000 a 100,000, y antes de que el control de cabras a gran escala empezara, el mismo transecto fue muestreado y documentado otra vez. En esta contribución, las descripciones de los sitios están resumidas, comparadas entre 1986 y 1996, e ilustradas con una serie de fotografías.

INTRODUCTION

Until recently, Alcedo was one of the most pristine volcanoes in Galapagos, despite the presence of a tourist trail to the rim of the crater. Until 1968, the only introduced vertebrate grazers were donkeys, whose impact on vegetation has been considered less than that of the large tortoise population (Fowler 1980, Werff 1982, Adsersen 1989). Fowler (1980) estimated the population of donkeys on Alcedo as 500–700.

Goats were first seen on Alcedo about 1968 (Perry 1968). Corley Smith (1981), De Vries & Black (1983) and Hoeck (1984) mentioned that a small number of feral goats from southern Isabela succeeded in crossing the rugged lava fields of Perry Isthmus to reach Alcedo some time between 1968 and 1979, but it is unclear whether this introduction was successful, and until the mid-1980s, numbers remained small and distribution restricted. Duffy (1981) optimistically reported that “the northern volcanoes of Isabela seemed to be tougher than the goats”. He recognized that the Galapagos National Park Service (GNP) was trying to eradicate these goats, and found no signs of a population explosion such as occurred on other islands in Galapagos such as Santiago and Pinta. Unfortunately, around 1990, goat populations on Alcedo rapidly increased to alarming numbers. Anecdotal evidence of habitat change on Alcedo, caused by the animals, began to be noted in the early 1990s (e.g. Freire 1992, Cayot & Snell 1996), especially destruction of the highland forests, increased erosion and possibly competition for food with tortoises. Feral goat numbers were estimated to be as high as 50,000 to 100,000 during the spring of 1996, before recent eradication efforts began, and more than 25,000 goats and some 680 donkeys were killed later in 1996 by GNP wardens (L. Cayot pers. comm). There was intermittent hunting from 1996 to 2000, and then suspension of the campaign until Project Isabela started hunting in 2004, when a goat population estimate of c. 40,000 was based on helicopter hunting kills that year (K. Campbell per A. Tye pers. comm.). Goats also moved to all the northern volcanoes, with groups spotted on Ecuador Volcano since 1999 (K. Campbell per A. Tye pers. comm.).
Dramatic events have taken place on Alcedo (Cayot & Snell 1996). Feral goats have seriously altered the natural vegetation. On large parts of the eastern slope and rim of Alcedo we noted that they nearly wiped out large stands of native vegetation. Forest and scrub had by 1996 been converted to grassland, possibly leading to shortage of food and shelter for native species, as well as enhancing soil erosion. Although these devastating effects of goats on Alcedo are obvious, few comparative data are available and photographic comparisons have not been published.

During the first week of April 1986, before the overwhelming presence of goats, we sampled terrestrial macro-invertebrates on Alcedo in nine sites along an altitudinal transect from the seashore to the top, including the eastern rim to the fumarole area in the south of the crater (Fig. 1), with an emphasis on beetles (Coleoptera) and spiders (Araneae) (Baert et al. 1989, Desender et al. 1989). The most obvious introduced mammals on Alcedo at that time were feral donkeys, which were not very abundant. Vegetation composition and structure at all sampling sites were described and photographs were taken. Details of methods, sampling techniques, invertebrate species and data analysis are given by Desender et al. (1999).

During the first week of April 1996, the transect was resampled and photographs repeated.

The vegetation on Alcedo is progressively more xerophytic towards the coast (Hamann 1981). Annual rainfall is usually lower near the coast, and soil looser and more humus-poor (Huttel 1995, Grant 1986, Wiggins & Porter 1971). Near the coast, the vegetation is relatively species-poor, with mainly Scalesia affinis or Waltheria ovata and some grasses during the wet season. Higher up on the eastern slopes, this semi-arid scrub gradually changes into a shrub savanna and deciduous forest, dominated by the tree Bursera graveolens and, somewhat higher, also by shrubs of Scalesia microcephala. From about 800 m altitude upwards, the vegetation gradually becomes evergreen steppe scrub, dominated by trees such as Pisonia floribunda, Psidium galapageium and Zanthoxylum fagara. Along the eastern and southern rim, treeferns and evergreen fern meadow originally occurred as patches between a dense and species-rich evergreen mossy forest, which was best developed above the former fumarole area (our site 9, cf. Hamann 1981).

To distinguish goat-induced changes in population dynamics from natural fluctuations related to climatic conditions, we investigated the response of invertebrates to the ecological gradient and/or climatic variability. By coincidence, meteorological conditions during both years appeared similar, especially precipitation, and both 1986 and 1996 could be classified as years with moderate rainfall. Even the timing of heavy rainfall prior to our sampling was more or less comparable: the most recent heavy showers took place about three to four weeks prior to each of the two sampling campaigns. Under such conditions it can be assumed that the majority of the terrestrial invertebrate species were equally abundant in the various habitats in the two years, another prerequisite for a meaningful quantitative ecological sampling and analysis. Our 1986 sampling sites had been damaged and overgrazed by feral goats to very different degrees by 1996, a prerequisite for any attempt to evaluate the influence of goats.

In the present paper, we describe and illustrate the Alcedo sampling sites by pictures taken during 1986 and 1996 at the same sites along the studied transect.

**COMPARISON OF THE SAMPLING SITES IN 1986 AND 1996**

The location of the sampling sites is shown in Fig. 1. Table 1 summarizes site data including elevation,

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<th>Sampling station</th>
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<td>evergreen steppe scrub</td>
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<td>evergreen fern meadow</td>
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<td>evergreen mossy forest</td>
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<td>trees and shrubs (1996)</td>
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<td>herb layer (1996)</td>
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<td>Goat damage* (1996)</td>
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*0 = no apparent alterations; 1 = slight but obvious damage; 2 = highly influenced.
Figures 2 (top) to 5 (bottom). NE slope and E crater rim of Alcedo Volcano. Left views (A) correspond to 1986, right views (B) to 1996. 2A–2B: Site 3, 400 m. 3A–3B: Site 4, 600 m. 4A–4B: Site 6, 900 m. 5A–5B: eastern crater rim from Site 7, 1000 m.
Changes in the vegetation between 1986 and 1996 were not obvious at elevations of 400 m and 600 m (Table 1, Figs 2–3). Changes became apparent from an elevation of about 800 m upwards to the rim: sites 5 and 6 (Fig. 4), both situated on the steepest parts of the volcano slope, appeared more open in 1996; reduction in vegetation appeared to be partially associated with increased erosion. Sites 7 to 9 (rim area, 1000–1060 m altitude) had been much more influenced (Figs 5–7): the evergreen steppe scrub and dense evergreen mossy forest had disappeared in many places, especially around the top (Fig 6) and at the rim (Fig. 7) above the fumarole that was active at the time, and had been replaced, at least during the wet season, by a more or less continuous short-grazed and species-poor meadow. Ferns and especially treeferns on many spots had been mostly destroyed; logs and stumps of dead wood were abundant (Fig. 8). At the rim we witnessed in 1996 the disappearing *Scalesia*, *Tournefortia* and *Zanthoxylum* patches (Fig. 7), bare patches of dying tree ferns (formerly nearly invisible due to luxuriant and dense woodland), increased erosion of the inner caldera slopes as well as a large part of the outer slopes of the volcano. Parts of the area had become dry and dusty during the annual dry season (L.
Cayot pers. comm.), where formerly interception of the misty clouds of the garúa by the former woodlands deposited much more moisture on the vegetation of herbs, grasses, trees and shrubs with epiphytic mosses and lichens. Giant tortoises, once largely hidden by the luxuriant vegetation (Fig. 9A), were visible from great distances in 1996 (Fig. 9B); note goats in the background. The area around the easternmost fumarole in the caldera also appeared to have been influenced (Fig. 10), with more open foreground in 1996 and increased erosion, although the most striking difference here was that the fumarole had become almost inactive by 1996 (cf. Green 1994).

Our reference dataset of photographs and invertebrate results may be used for future monitoring in the area, especially the expected recovery of vegetation and associated invertebrate communities during and following goat eradication.

**ACKNOWLEDGMENTS**

Excellent cooperation and field logistic support were provided by the Charles Darwin Research Station, Santa Cruz, Galapagos (G. Reck and C. Blanton, Directors and their staff) and the Galapagos National Park Service (F. Cepeda and A. Izurieta, Superintendents, Dept. Forestry, Ministry of Agriculture). TAME airline kindly issued reduced price tickets. Our investigations and field work were financially supported by the Belgian DWTC (former Ministry of Education), the National Fund for Scientific Research (FWO) and the Leopold III Foundation. Help in field sampling was obtained from S. Abedrabbo and S. Sandoval. Information on Alcedo up to 1996 was kindly provided by L. Cayot. The manuscript was improved by comments from K. Campbell and A. Tye. This is Contribution 1020 of the Charles Darwin Foundation for the Galapagos Islands.

**LITERATURE CITED**


FISHERY BYCATCH OF THE WA VED ALBATROSS PHOEBASTRIA IRRORATA, A NEED FOR IMPLEMENTATION OF AGREEMENTS

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SUMMARY

The Waved Albatross, a threatened Ecuadorian endemic bird, is protected by national and international laws and agreements, in spite of which, 43 that had been ringed on the island of Española, Galapagos, were found killed off the coast of Peru, at least 34 of them by incidental fishing. International collaboration is required for the effective conservation of this species.

RESUMEN

Pesca incidental del Albatros de Onda Phoebastria irrorata, una necesidad para la implementación de acuerdos. El Albatros de Onda Phoebastria irrorata, es una ave amenazada, endémica del Ecuador, la cual está protegida por leyes nacionales y acuerdos internacionales, pese a esto, 43 individuos anillados en la isla Española, Galápagos, fueron encontrados muertos en la costa del Perú, al menos 34 de estos fueron por pesca incidental. La colaboración internacional es necesaria para una conservación eficaz de esta especie.

INTRODUCTION

The Waved Albatross Phoebastria irrorata is endemic as a breeding species to the Galapagos Islands (Jiménez & Wiedenfeld 2002), except for a few pairs that breed on Isla de la Plata off the coast of Ecuador (Granizo 2002). It is Vulnerable (IUCN 2006) but a proposed move to Critically Endangered (B1a,b(ii,iii,iv,v)) is currently under discussion.