Advances in the conservation of threatened plant species of Galapagos

Rachel Atkinson[1], Patricia Jaramillo[1], Walter Simbaña[1], Anne Guezou[1] & Vanesa Coronel[2]

1 Charles Darwin Foundation
2 Agricultural University of Sweden

Introduction

Oceanic island floras show high levels of endemism but are usually severely threatened by introduced species and habitat alteration. Due to the limited land area, population sizes tend to be small naturally and are thus even more susceptible to extinction. The flora of Galapagos is no exception. A recent analysis by Tye (2007) suggests that 60% of 168 endemic plant species are threatened according to IUCN Red List criteria. These species have become increasingly rare due to the impact of introduced herbivores and development. Management actions have been carried out in an attempt to reverse population declines for many of these species, with action ranging from island-wide eradication programs to localized fencing to prevent damage from humans and herbivores. Sometimes, however, these actions have not led to population recovery and further studies are required to understand what other factors may be limiting the species.

This paper reports on the advances made in the conservation of 18 of the rarest endemic plants in Galapagos over the last ten years. To provide specific examples that illustrate the complexity of plant conservation, the actions and research carried out for individual species have been grouped into three sections: (i) preventing herbivory; (ii) reducing the impact of development; and (iii) understanding life histories.

1. Preventing herbivory

Introduced herbivores are known to be one of the greatest threats to plant biodiversity. Two strategies have been adopted in Galapagos to remove the impact: island-wide eradication of introduced herbivores and localized protection through fencing.

a) Island-wide eradications

After many years of herbivore control, Santiago and Floreana have joined an increasingly long list of islands free of goats, donkeys, and pigs (Lavoie et al., 2007). Three threatened plant taxa on Santiago and six on Floreana have been studied during this period to determine the effect of herbivore eradication. Some species have shown a dramatic increase in their abundance following herbivore eradication (Table 1).

For seven of the taxa, the number of known populations has increased. Six of the species show a marked increase in total population size, even though not all populations were surveyed in 2007. The only species that does not show a population increase is *Alternanthera nesiotes*, but this may be a consequence of limited sampling. All species had juveniles present in 2007, evidence of active population growth.

b) Fencing individual populations

To date it has not been possible to eradicate introduced herbivores from all islands and fences have been used to provide localized protection. Here we report on ten fencing projects that were undertaken to protect populations of five threatened species from herbivory on the inhabited islands of Isabela (Volcán Sierra Negra), Santa Cruz, and San Cristóbal. Fences range in size from 25 m^2 to several hectares, protecting one individual to entire local populations (Table 2).

Unfortunately, it has been difficult to quantify the net conservation effect of the fences on the survival of the threatened species. While fences protect plants from herbivory, they can sometimes lead to other problems, such as allowing excessive growth of competitive plants.

2. Reducing the impact of development

The increasing human population in Galapagos is leading to encroachment into the natural ecosystems. Habitat alteration over even very small areas can impact heavily on island floras due to the presence of restricted-range endemics. However, it can also have surprising results. Below are two contrasting examples from Santa Cruz:

a) *Scalesia affinis*

Scalesia affinis (a beautiful small tree with tobacco-shaped leaves and white, daisy-like flowers) has been reduced to 71 plants on Santa Cruz (Jaramillo,unpublished 2005). Most of these individuals are located at the edge of Puerto Ayora in a zone used in recent decades for rock extraction and rubbish dumping but now demarcated for a new housing development. Other isolated individuals occur along the road near to a recently built office complex and several were destroyed during construction of the village bus terminal.

To prevent further destruction, two small fences were built in 2005 to protect three individuals located close to the main road. In 2007 a larger fence was built to protect the remaining unfenced plants (Table 2). The fences have successfully protected the individuals but the long-term survival of the last population on Santa Cruz is uncertain given the demand to develop the surrounding land.

b) *Acalypha wigginsii*

Acalypha wigginsii (an unremarkable straggling woody herb that grows up to 1 m tall) is restricted to the fern-sedge zone on the ridge of Cerro Crocker on Santa Cruz. In 2000 a new telecommunications antennae was built on the top of the hill, destroying the largest known population of this species and reducing the total population to 100 plants. As a result the species was classified as Critically Endangered (Tye, b;2002).

In response to concern over its future, the species has been monitored since 2001. Unexpectedly, the population has increased over this period (Figure 1). Although the vegetation on the ridge has become invaded by introduced plant

species, periodic weeding around the antennae and access trails appears to help *A. wigginsii*, as it tends to colonize open ground. This finding has led to new management recommendations for the long-term survival of this species.

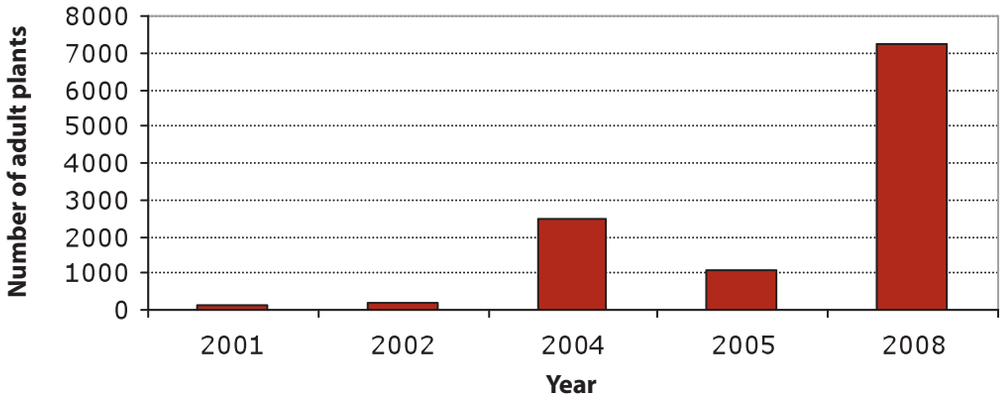

Figure 1. Population size of *Acalypha wigginsii* since the construction of the antennae on Cerro Crocker in 2001.

3. Understanding life histories

Many threatened species have not responded as expected to the management techniques discussed above. In these cases, more detailed studies will help to determine what is limiting population recovery. We present three examples to show the range of problems that can affect species: (i) a naturally low viable seed production in *Scalesia affinis*; (ii) the lack of suitable climatic conditions for germination of *Lecocarpus lecocarpoides*; and (iii) the complexities of plant-herbivore interactions in the restoration of *Opuntia megasperma var orientalis* on Española.

a) *Scalesia affinis*

Unlike most Galapagos endemics, *S. affinis* is known to be partially self-incompatible (McMullen, 1987; Nielsen et al., 2007) and the wild population of this species in Santa Cruz shows very little natural regeneration suggesting there is little outcrossing occurring. Cross-pollination experiments were carried out throughout 2007 to determine if viable seed set could be increased. By the end of the year, 60 young plants had been produced in the nursery from 860 viable embryos, indicating severe reproductive difficulties. These plants have been used to found a new population, although the long-term success of this population will need to be monitored.

b) *Lecocarpus lecocarpoides*

L. lecocarpoides (a pretty shrub with yellow daisy flowers and serrated light green leaves), listed as Endangered (Tye, 2007), is endemic to Española and the four surrounding islets of Oeste, Osborn, Gardner, and Tortuga. All populations fluctuate widely in size, and although relatively common on the islets (a total of 1000 plants being recorded in 2007), only a single individual was recorded at Punta Manzanillo in 2007, suggesting the need for urgent action to avoid local population extinction. Seedbank sampling to a depth of 5 cm in a 2 m^2 plot around the remaining plant resulted in 424 seeds. Results from viability testing of the other populations indicate that about 80% of the seeds are viable. If the hard outer seed coat is broken, the seeds germinate within two days, growing to maturity in three months. It would thus appear that this species is very dependent on specific climatic conditions for population recruitment, conditions that may occur infrequently in Galapagos. Information such as this is essential to understand better the dynamics of the population and determine pragmatic conservation management plans.

Photograph: Mandy Trueman

c) *Opuntia megasperma* var. *orientalis*

O. megasperma var *orientalis* (a fat tree cactus with a long straight trunk topped with a crown of cactus pads) is found on San Cristóbal and Española and is IUCN red listed as Endangered (Tye, 2007). The population on Española was severely damaged by goats. However, goat eradication in 1978 has not yet resulted in the recovery of this keystone species, even after 30 years.

It seems unlikely that the reproductive system is limiting the recovery of Opuntia as fruits are regularly produced, seed viability is high (an average of 74% across the three main populations; Coronel, 2000), and seedlings are easy to propagate *ex-situ*.

Opuntia is a favorite food of tortoises and an intensive captive breeding program, initiated in the 1970s, has released over 1 000 tortoises back onto the island (Marquez *et al.*, 2003). To test whether this artificially rapid "recovery" of the natural herbivores has been too fast to allow for cactus regeneration, a caging experiment was begun in 2007. Preliminary results show that cages do help increase survivorship of young plants and pads; all the pads outside of the cages were eaten, suggesting that the interaction between tortoises and Opuntia may be an important component in the recovery of this species (Coronel, 2002).

Conclusion

The information presented above on 18 of the rarest plant species in Galapagos shows the complexity and diversity of problems associated with their conservation. One constraint to understanding the response of management actions by individual plant species has been the lack of consistent monitoring protocols and robust experimental design. Part of the reason for this is the degree of crisis management involved in the conservation of species on the brink of extinction. However, as many of the more detailed case studies show, species response to simple management measures is idiosyncratic, and species need to be considered individually within their natural ecosystem to determine whether management actions have aided their recovery.

Evaluating the effectiveness of a decade of conservation measures is an important exercise to both reveal new trends and optimize future action so that the threatened plants of Galapagos can persist in the long term.

Table 1. Changes in the population size and number of nine threatened plant species with herbivore eradication on Floreana and Santiago.

Taxon (IUCN Theat category*)	Island	Population information prior to herbivore eradication				Population information post herbivore eradication			
		Year	No. adults	Seedlings to adult ratio	No. populations	Year	No. adults	Seedlings to adult ratio	No. populations
Scalesia affinis (VU)	Floreana	2000[3]	100	not known	2	2007	299	0.3/1	3
Alternanthera nesiotes (EN)	Floreana	1998[1]	4500	0.6/1	5	2007	>715 [a]	0.1/1	10
Lecocarpus pinnatifidus (CR)	Floreana	2004[3]	1000s	not known	6	2007	>6000 [b]	1.9/1	13
Lippia salicifolia (CR)	Floreana	1998[1]	2600	0.5/1	10	2007	1591	0.8/1	10
Psychotria angustata (CR)	Floreana	1998[1]	250	0.1/1	3	2007	264	4.5/1	4
Linum cratericota (CR)	Floreana	1998[1]	13	not known	1	2007	300	0.7/1	1
Scalesia atractyloides var. *atractyloides* (EN)	Santiago	1998[2]	2	not known	1	2007	>21 [c]	0.5/1	4
Galvezia leucantha subsp. *porphyrantha* (EN)	Santiago	2000[2]	130	not known	3	2007	>220 [d]	0.4/1	6
Scalesia atractyloides var. *darwinii* (EN)	Santiago	1995[2]	5	not known	1	2007	>1404 [b]	1.6/1	12

*CR: Critically Endangered, EN: Endangered, VU: Vulnerable. Taken from Tye (2007)

[1] Mauchamp *et al.* (1998), [2] Tye & Jaeger (2000), [3] CDF unpublished data

[a] 3 populations surveyed, [b] 11 populations surveyed, [c] 1 population surveyed, [d] 5 populations surveyed

Table 2. Details of the fences built to protect six threatened plants species from herbivory and human activities.

Taxon (IUCN Theat category*)	Island	Date of fencing	Location	Area fenced (m^2)	Reason for fencing	Number of individuals fenced	% of local population protected	% of total individuals protected	Notes
Scalesia cordata (EN)	Isabela	1993, enlarged in 2000	Bosque de los niños	240	pigs, cattle	20	100	46	The last population within the agricultural zone
		2006	Cerro Colorado (Sierra Negra)	10,000	pigs	77	20		One of 13 populations within the National Park
Calandrinia galapagosa (CR)	San Cristóbal	1993	Cerro Colorado	320	people, goats, donkeys	89	70	57	Donkeys have also been controlled in the area
		2003	Ripioso	10,000	goats, donkeys	380	100		This fence also protects *Lecocarpus leptolobus*
		2005	Bahía Rosa Blanca	100	goats	3	40		
Darwiniothamnus alternifolius (CR)	Isabela	2006	Sierra Negra	625	pigs, cattle	35	5	100	
		2008	Sierra Negra	20,000	people, pigs,cattle, horses	1300	100		80% of the plants within the fence are seedlings
Scalesia affinis (VU)	Santa Cruz	2005	Puerto Ayora	25	people, donkeys	1	1	100	Plant grows in an area under development
		2005	Puerto Ayora	25	people	2	5		Plant grows in an area under development
		2007	Terminal Terrestre	14,400	people	65	80		Plants grow in an area under development
		2008	Carretera Garrapatero	10,000	people, donkeys	3	100		
Lecocarpus darwinii (EN)	San Cristóbal	1993, rebuilt in 2000	Cerro Colorado	320	goats, donkeys	280	80	56	Donkeys have also been controlled in the area
Lecocarpus leptolobus (CR)	San Cristóbal	2003	Ripioso	10,000	goats, donkeys	110	100	77	This fence also protects *Calandrinia galapagosa*

*CR: Critically Endangered, EN: Endangered, VU: Vulnerable. Taken from Tye (2007).