Establishing a new population of *Scalesia affinis*, a threatened endemic shrub, on Santa Cruz Island, Galapagos, Ecuador

Rachel Atkinson[1*], Patricia Jaramillo[1] & Washington Tapia[2]

[1]*Charles Darwin Foundation, Santa Cruz, Galapagos, Ecuador*
[2]*Galapagos National Park Service, Santa Cruz, Galapagos, Ecuador*

Corresponding author e-mail: ratkinson@fcdarwin.org.ec

SUMMARY

Scalesia affinis is a threatened shrub endemic to the Galapagos archipelago. Its population on the island of Santa Cruz is critically endangered, with only 71 adult plants known. The future of these individuals is unclear due to imminent development of land surrounding the largest population. This paper reports on a project to establish a new population of *S.affinis* on Santa Cruz within its historical native range from plants grown *ex situ*. As the plant is known to be self-incompatible, cross pollination was carried out in the wild to try and augment viable seed production. Average seed viability from 22 artificial crosses was 0.58 (SE ± 0.043), a level similar to naturally produced seeds. Survivorship from germination was low, with only 17% of plants surviving to three months post germination. Survival following transplanting out in the wild was also low, with just 19% of plants (11 out of 57) alive after one year. The relative roles of genetic and environmental factors are discussed in relation to these results.

BACKGROUND

Scalesia affinis (Asteraceae) is a flowering shrub that grows to about 3 m tall. It is one of 22 taxa from the radiation of the endemic genus *Scalesia* in Galapagos. It grows in the arid and transitional zones, and although found on four of the 13 main islands that comprise the archipelago, genetic analysis indicates that the populations on each island should be considered as separate units of conservation value (Nielsen 2004). While still common on the uninhabited slopes of the volcanoes of Alcedo (Isabela Island), and Fernandina Island, only very small populations exist on the volcano Sierra Negra (Isabela) and the islands of Floreana and Santa Cruz (Fig. 1).

Although reportedly common as little as 30 years ago (Syuito Ito *pers. comm.*), the population on Santa Cruz appears to have been reduced to just 71 adult plants (Jaramillo 2005). Unlike most Galapagos endemics, *S.affinis* is known to be partially self-incompatible (McMullen 1987, Nielsen *et al.* 2007, Nielsen *et al.* 2003) and the wild population of this species in Santa Cruz shows very little natural regeneration, suggesting problems with the production of viable seeds. In addition, most of these individuals are located at the edge of the island´s one coastal town of Puerto Ayora in a zone used in recent decades for rock extraction and rubbish dumping. To prevent destruction of the extant plants, enclosures have been recently constructed: two small enclosures were built in 2005 to protect three individuals located close to the main road; in 2007 a larger enclosure was built to protect the remaining unfenced plants. The fences have successfully protected these individuals but the long-term survival of this last population on Santa Cruz is uncertain given that the surrounding land has been allocated by the government for a new housing development.

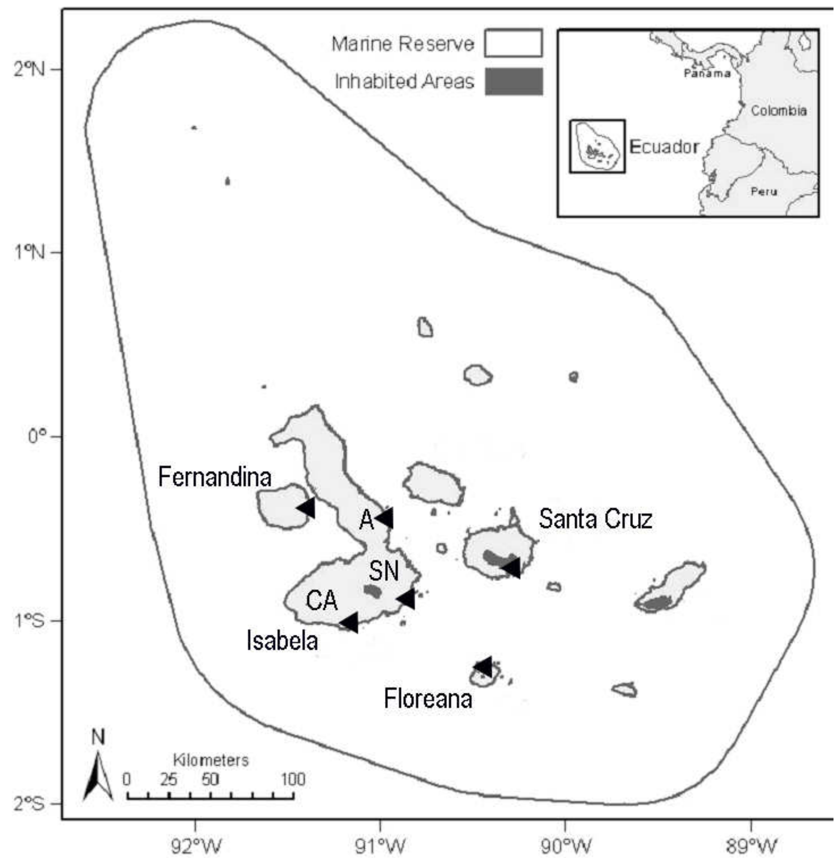

Figure 1. Approximate distribution of S*calesia.affinis*; this Galapagos endemic is known from the islands of Isabela (on the volcanoes of Alcedo (A), Sierra Negra (SN) and Cerro Azul (CA)), Fernandina, Floreana and Santa Cruz. Main distribution indicated by black triangles. The shaded areas indicate main human-inhabited zones of the archipelago.

As a result we decided to attempt to establish a new population of *S.affinis* within its known historical range, but away from land currently being developed and that proposed for future development, using young plants propagated *ex-situ*. An area of one hectare was chosen on the eastern side of the island, surrounding one of the two remaining plants that persist there. The area was fenced to protect the new population from herbivory by introduced free-ranging donkeys *Equus asinus* and goats *Capra hircus*. In this paper we describe the actions taken to propagate plants through *ex-situ* production, and the first year survival of the young plants following transplanting out in the wild.

ACTION

Production of viable seeds: Cross-pollination experiments were carried out throughout 2007 to determine if the number of viable seeds set could be increased *in situ.* Crosses were carried out between every combination of plants possible in the wild population, dependent on the availability of pollen and open flowers. Flower buds were enveloped in separate muslin bags and observed regularly until open and full of pollen. Pollen was then collected and transferred to another open flower on a different plant using a fine paint brush. The cross was recorded, and the recipient flowers replaced into bags. Ripe seeds (ready after about 4 weeks subsequent to pollination) were collected from each flower. In addition to outcrossing, artificial self-pollinations were carried out, and seeds were also collected from natural pollinations. Viable seeds were identified in the laboratory as those that were larger, harder and sink in water.

Of 675 seeds collected from manual cross pollinations, mean viability of seeds per cross (± 1 SE) was 0.58 ± 0.043 (n=22). This was similar to the viability from natural (wild) pollination events at 0.59 ±0.033 (n=3), but higher than the viability of seeds from artificially self-pollinated plants 0.37 ±0.063, (n=5) (One-way ANOVA, $F_{2,27}$ = 2.76, p =0.08; Fig. 2).

Germination and growth of plants *ex situ*: Viable seeds were soaked for six days in fresh water to allow easy extraction of the embryo. The embryo was then planted either onto absorbent paper in a Petri dish or into a pot containing very fine soil. Embryos left to germinate on the Petri dish were planted on the second day in soil, before the roots attached themselves to the paper. Deep pots (30 cm depth) were used to accommodate the long tap roots. During transplanting, care was taken to avoid damaging root systems which might otherwise have caused high levels of mortality. By the end of the year (2007), 92 young plants had been produced in the Charles Darwin Foundation nursery (on Santa Cruz) from 548 embryos that germinated. Overall, more plants from out-crosses survived (χ^2 =10.94, p<0.001, n=3), but the mean proportion of offspring survival by cross did not differ with type of cross (One-way ANOVA $F_{2,27}$ = 0.22, p=0.8; Fig. 3).

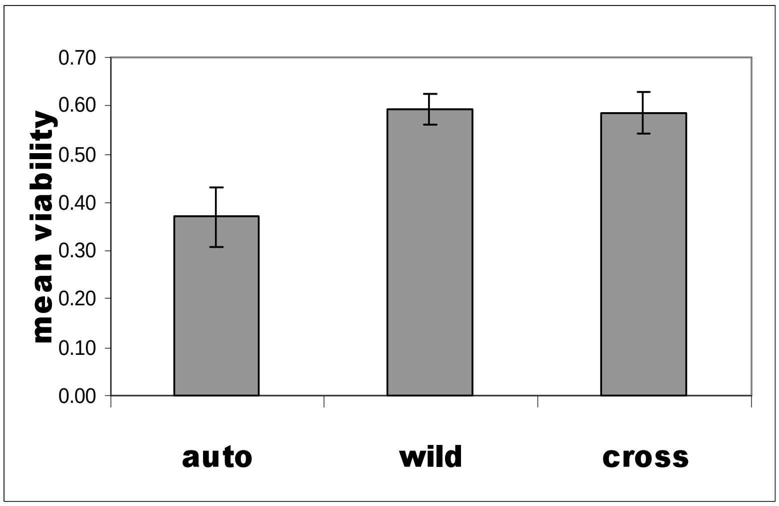

Figure 2. The mean (± 1 SE) proportion of viable *Scalesia* embryos per cross type (auto = artificially self-pollinated; wild = naturally pollinated; cross = artificially cross-pollinated).

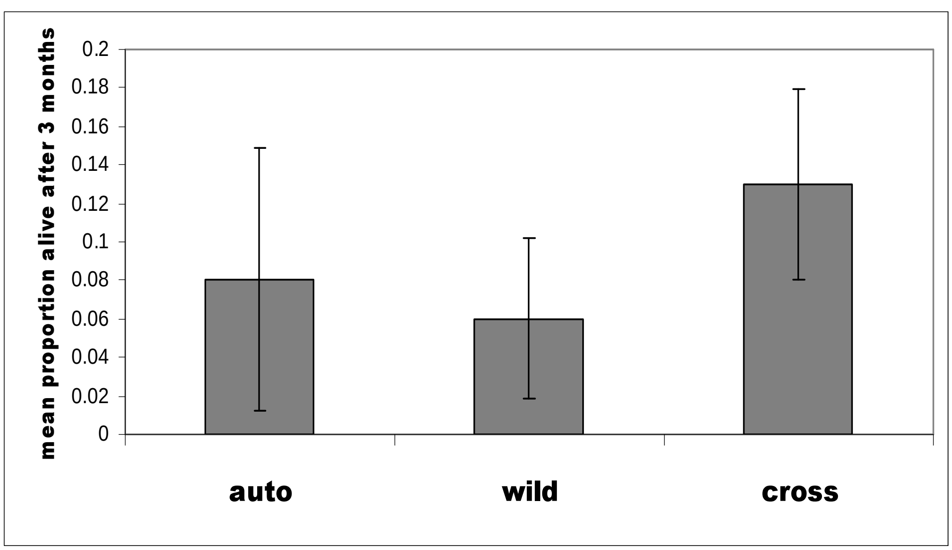

Figure 3. The mean (± 1 SE) proportion of *Scalesia* plants surviving per cross type after three months, Santa Cruz, 2007.

Transplanting into the fenced enclosure: Of the 92 nursery-grown plants, 53 were transplanted into a 1 ha enclosure (containing one existing extant adult plant) located on the eastern side of Santa Cruz in April (i.e. the rainy season) 2008. The 1 ha area was fenced to ensure that no large mammals (i.e. feral goats and donkeys) could gain access. Four plants were planted outside the fence to assess the impact of these introduced herbivores. Individual plants were chosen to represent every cross that had resulted in offspring, with replicas of a few crosses to provide sufficient plants. One month before translocation, the plants were put in full sun, and the amount of water given to each plant reduced substantially to acclimatize the plants to field conditions.

Due to the rocky terrain, plants were put where enough soil was present in which to plant them. Each plant was watered immediately following planting, but no follow-up watering was carried out in order to force adjustment to local conditions. No other care was provided following transplanting; 2008 was an exceptionally wet year.

Monitoring: The 57 transplants were monitored in May 2008 (4-weeks after planting), and then monthly from October 2008 to January 2009, and again in May 2009 to determine survivorship, and the cause of death, as and when it occurred. The variable time between monitoring periods was due to constraints of staff availability.

CONSEQUENCES

Plant survival: In May 2009, i.e. one year after planting out, of the 57 individuals only 11 were alive (19%; Fig. 4). This is in comparison to the one remaining natural adult plant fenced within the area that produced 25 offspring in April 2008, all of which were still alive a year later. Relatively few of the plants died over the first seven months (53% were alive in May 2008 and still persisting in October 2008). Most died between October 2008 and February 2009. There were no indications of herbivory on the four individuals planted outside of the fenced area, all of which were alive in May 2009.

Plants chosen for planting out were selected to maximize the representation of different crosses, and a total of 37 crosses were used. The number of individuals planted, and their survival one year later is shown in Table 1. Although individuals were not chosen to look at between cross survivorship, it would appear that two of the crosses (unknown father and code 16 mother, and father code 18, mother code 11), had a higher survival than expected.

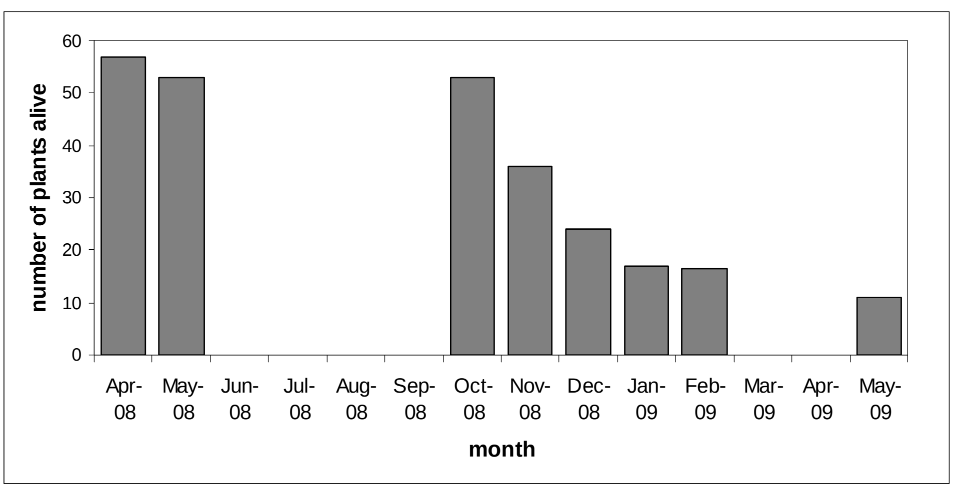

Figure 4. Survivorship of *Scalesia* plants over the first year since planting out in eastern Santa Cruz.

Table 1. Survivorship of each of the 57 individuals transplanted into the wild, by parental cross.

Code for father	Code for mother	Number planted (April 2008)	Number alive (May 2009)
?	16	3	2
1	1	1	0
1	4	1	0
1	6	1	1
1	9	2	1
1	21	3	1
2	1	1	1
3	24	1	0
4	12	2	0
5	9	1	0
6	25	1	0
6	11	2	0
7	26	1	0
8	27	1	0
9	27	2	0
10	10	4	0
10	26	1	0
10	12	1	0
11	13	1	0
12	11	1	0
13	14	2	0
13	16	1	0
14	15	1	0
15	28	1	0
16	29	1	0
16	18	1	1
16	22	2	0
17	16	2	0
17	30	1	0
17	28	1	0
18	11	3	3
19	15	1	0
19	16	2	0
20	22	1	0
21	31	1	0
22	23	3	1
23	16	2	0
TOTAL		**57**	**11**

Conclusions: The establishment of a new population of *Scalesia affinis* has not been straightforward, as evident from the high mortality of the 57 individuals that were transplanted. In comparison, of 25 seedlings that germinated in 2008 from naturally set seed around the single remaining wild tree within the enclosure, all were still alive one year later. There is no evidence that the fencing enhanced survival of these seedlings; 2008 was an exceptionally wet year, and it may be that wet years such as this may be the source of the next cohort. The dead plants were small, having not appeared to have grown since planting out. The period of highest mortality, between November 2008 and January 2009, is normally the beginning of the rainy season in the arid zone in Galapagos, but, following unusually heavy rains until mid-2008, there was very little precipitation at the end of the year. However, individuals of *S.affinis* planted in gardens also died suddenly during 2008 (even with watering), while others planted at the same time are thriving and healthy (*pers. obs.*). The arid lowlands of Galapagos are generally dry, and much of the ground is covered with sheets of lava. *S.affinis*, which manages to stay green all year round, appears to be adapted (in part at least) to drought conditions by developing a long taproot. If individuals are planted out in areas where they cannot find a suitable crack in the lava for their taproot to extend down to sufficient depth, it seems unlikely that they will be able to obtain the water necessary for survival. However, it is very difficult to determine suitable micro-sites for planting on an individual plant basis, which may be one reason for the resultant high levels of mortality observed in these planting trial and the unexplained deaths of plants in gardens.

In addition, and as indicated by the data from viable seed set, germination and survival, the species seems to have a very high natural mortality throughout each growth stage, which may be at least partly due to inbreeding (Nielsen *et al.* 2007). Further work is needed to determine the relationship between the remaining adult individuals and to test decisively the role of inbreeding depression in the viability of this population. This will help inform future propagation programmes.

ACKNOWLEDGEMENTS

We acknowledge the participation of many volunteers at the Charles Darwin Foundation and park-rangers from the Galapagos National Park Service. We thank Lene Nielsen and Marienne Philipp for experimental advice, and Alan Tye for initiating the project. Comments on the manuscript were gratefully received from Steve Blake. Funding for the work and the fencing material was provided by the Stanley Smith Horticultural Fund (UK), The J.Q. Worthington Foundation Inc., Frankfurt Zoological Society, the Kiedanren Nature Conservation Fund, the Cybec Foundation and Galapagos National Park Service.

REFERENCES

Jaramillo P. (2005) *Scalesia affinis, "la Scalesia de Puerto Ayora" casi extinta en Santa Cruz.* Fundacion Charles Darwin Report, unpublished.

McMullen C.K. (1987) Breeding systems of selected Galápagos-Islands angiosperms. *American Journal of Botany*, **74**, 1694-1705.

Nielsen L.R. (2004) Molecular differentiation within and among island populations of the endemic plant *Scalesia affinis* (Asteraceae) from the Galápagos Islands. *Heredity*, **93**, 434-442.

Nielsen L.R., Siegismund H.R. & Hansen T. (2007) Inbreeding depression in the partially self-incompatible endemic plant species *Scalesia affinis* (Asteraceae) from Galápagos islands. *Evolutionary Ecology*, **21**, 1-12.

Nielsen L.R., Siegismund H.R. & Philipp M. (2003) Partial self-incompatibility in the polyploid endemic species *Scalesia affinis* (Asteraceae) from the Galápagos: remnants of a self-incompatibility system? *Botanical Journal of the Linnean Society*, **142**, 93-101.