THE SUCCESSFUL CONTROL OF *ORTHEZIA INSIGNIS* ON ST. HELENA ISLAND SAVES NATURAL POPULATIONS OF ENDEMIC GUMWOOD TREES, *COMMIDENDRUM ROBUSTUM*

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ABSTRACT

The small South Atlantic island of St. Helena has a highly degraded but internationally significant terrestrial flora, now covering only 1% of its land area. The 2500 gumwood trees, *Commidendrum robustum*, in the last two natural stands, are an important part of this remnant flora. In 1991, a scale insect infesting the gumwoods was identified as *Orthezia insignis*. This South American pest is widespread in the tropics, but this was the first record from St. Helena. By 1993, there were severe patches of infestation of the scale, and over 100 gumwood trees were dead. If the exponential increase in the number of dead trees had continued, all 2500 trees would have been killed by 1995. This was a likely outcome given the lack of natural enemies, and abundance of alternative host plant species for the scale. Fortunately, *O. insignis* had a history of successful biological control in Hawaii, and several African countries, through the introduction between 1908 and 1959 of the predatory South American coccinellid beetle, *Hyperaspis pantherina*. The life history and environmental safety of the predator were studied in quarantine in the U.K., and in 1993 the St. Helena government gave permission for its introduction onto the island. In May 1993, 80 *H. pantherina* survived the 6-day journey to St. Helena, and were used to establish a laboratory colony, from which over 5000 beetles were released from June 1993 to February 1994. Monitoring was undertaken using visual counts of *O. insignis* and *H. pantherina* on 300 labelled branchlets on the gumwood trees. Although the cause of tree death was visually obvious, monitoring demonstrated significant correlations between the levels of attack by the scale and tree mortality. *H. pantherina* was detected on the labelled shoots in February 1994, and numbers then increased, coinciding with a 30× decrease in mean scale numbers. This measured reduction is conservative, because the number of live scales tended to be underestimated when debris from recent feeding by the coccinellid was present. There have been no further problems reported with the scale on St. Helena since 1995. Laboratory rearing of *H. pantherina* was discontinued in July 1995 because insufficient *O. insignis* could be found anywhere on the island. Biological control of *O. insignis* was successful, but the extensive blackening from sooty moulds on all surviving gumwood trees in February 1995, suggested that the predator was effective only just in time to prevent most of

the trees being killed. Experimental transfers of *O. insignis* showed that the other three members of the endemic genus *Commidendrum* could also be at risk from the scale. The deliberate introduction of *H. pantherina* into St. Helena is an early example of biological control being initiated solely for conservation of indigenous biodiversity. It appears that this successful programme has saved the field population of a rare endemic plant from extinction.

INTRODUCTION

The 122-km^2 island of St. Helena is situated in the South Atlantic Ocean (15° 56´ S, 5° 42´ W). Despite widespread environmental degradation since the 16th century, the extant biota of the island is of international significance (Pearce-Kelly and Cronk 1990). St. Helena's flowering plants, for example, include 30 endemic species in 23 genera, and 10 of these genera are also endemic (Pearce-Kelly and Cronk 1990). Native vegetation covers less than 1% of the land area, and many of the indigenous plant species exist in only very small numbers (Cronk 1989). On the positive side, plant species thought to be extinct for over 100 years have been rediscovered, and ambitious restoration programs have been started (Cronk 1989). The endemic genus *Commidendrum* contains four species, including *C. robustum* (Roxb.) DC. (St. Helena gumwood) (Asteraceae), the island's national tree. The once extensive forests of gumwoods are now represented by 2500 trees in two small stands.

In 1991, an insect was noticed attacking gumwood trees at Peak Dale (G. Benjamin, pers. comm.) (Fig. 1). This was identified as the South American scale, *Orthezia insignis* Browne (Homoptera: Ortheziidae), a polyphagous pest that has been accidentally introduced into many tropical countries on imported plants. The first gumwood deaths attributed to *O. insignis* occurred in 1992. Control of *O. insignis* using insecticides was not an option because of the steep terrain, strong winds and risk to indigenous insects. CAB International suggested biological control as an option.

Figure 1. Gumwood branch heavily infested with *Orthezia insignis*, Peak Dale, St. Helena, May 1993. Note the blackening from sooty molds. UGA1390005

A predatory beetle, now known as *Hyperaspis pantherina* Fürsch (Coleoptera: Coccinellidae) (Fig. 2), was a recognised biological control agent for *O. insignis*, but because of poor past monitoring it's success record was uncertain, and little was known about it's biology. Consequently, the first steps were to review the past record of the agent, and study its life history with an emphasis on assessing its host specificity and optimising methods for rearing and transportation.

Figure 2. Adult *Hyperaspis pantherina*. UGA1390006

PAST USE OF *HYPERASPIS PANTHERINA* FOR BIOLOGICAL CONTROL OF *ORTHEZIA INSIGNIS*

Attempts to control *O. insignis* biologically using *H. pantherina* began with the first introduction of just five individuals from its native Mexico to Hawaii in 1908 (Clausen 1978). Since then *O. insignis* has reportedly been under effective control by *H. pantherina* (Zimmerman 1948). In 1948, *H. pantherina* from Hawaii were introduced into Kenya: *O. insignis* is no longer considered a major pest in Kenya, which again was attributed to *H. pantherina* (Greathead 1971). From Kenya, *H. pantherina* was distributed to Tanzania, Uganda and Malawi, where reports indicated that control of *O. insignis* was generally successful (Greathead 1971), although the outcome was disputed in Malawi. *H. pantherina* is the only biological control agent for *O. insignis* that has definitely established and achieved substantial control of the pest, although the evidence for this is non-quantitative and often anecdotal (Booth *et al*. 1995).

BIOLOGY AND CULTURING OF *ORTHEZIA INSIGNIS* AND *HYPERASPIS PANTHERINA*

Orthezia insignis is a mobile scale insect, which as an adult female has a large wax ovisac (Fig. 3). The species is parthenogenetic. The eggs hatch inside the ovisac and the 1st instar nymphs then move out to feed. *Orthezia insignis* was reared in large cages on various plant species as described by Booth *et al*. (1995).

Hyperaspis pantherina is difficult to rear successfully in large cages because the supply of prey can easily become exhausted, resulting in cannibalism by the predator, and collapse of the culture. Rearing methods were developed that used large numbers of small containers, with fresh *H. pantherina* eggs (normally attached to an adult scale) transferred into fresh containers every 2-3 days (Booth *et al*. 1995). Regular transfers of eggs, and provision of prey, reduced cannibalism because there were only small numbers of *H. pantherina* at similar growth stages in each container. After hatching, the first instar larvae of *H. pantherina* usually enter the ovisac of the female scale, where they consume scale eggs and hatching nymphs. *Hyperaspis pantherina* larvae normally became visible in the containers in the third instar when they leave the ovisac, in the process they normally kill and consume the adult scale.

When four female *H. pantherina* were closely observed for their adult life, over 90% of the total of 657 eggs produced were laid on adult female *O. insignis*. Almost all of the eggs laid on female *O. insignis* were either on the dorsal surface of the abdomen (Fig. 3) or on the dorsal surface of the ovisac. The few eggs laid on the substrate include those laid on the exuviae of *O. insignis*, on other fragments of the prey, nearby on the host plant, and on other suitable surfaces such as filter paper. In the complete absence of *O. insignis* as live individuals, exuviae or other remains, only one egg was laid in nearly 2 years of culturing. That *H. pantherina* almost never laid eggs in the absence of *O. insignis* (insects, exuviae or debris after predation), and that over 90% of eggs were laid on the adult female scales, suggest a very close predator-prey relationship. However, when deprived of *O. insignis*, caged adult beetles did attack *Planococcus* and *Pseudococcus* species (Homoptera: Pseudococcidae) (Booth *et al*. 1995). A risk of attack on other mealybug or scale species (Homoptera: Coccoidea) on St. Helena was not considered important, as all such insects recorded on the island are accidental introductions, and most are pests (Booth *et al*. 1995; Fowler 1993).

Figure 3. Adult *Orthezia insignis* with the 0.7mm oval, grey egg of *Hyperaspis pantherina on its abdomen*. UGA1390007

SHIPMENT TO ST. HELENA, REARING, AND RELEASE

St. Helena is remote, with the fastest access route being a military flight from the U.K. to Ascension Island, followed by a sea voyage to the island itself. No *O. insignis* were allowed in the shipment of *H. pantherina*, so the predator had to survive on water and honey agar (details in Booth *et al*. 1995). In May 1993, 80 larvae, pupae and adults of *H. pantherina* survived the 6-day journey to St. Helena, and were used to initiate a rearing programme using the methods previously developed. The first releases of *H. pantherina*, from June to November 1993, used a total of approximately 50 surplus ovipositing females from the laboratory culture. Each female was placed into a small 1mm mesh sleeve enclosing a scale-infested gumwood branchlet at Peak Dale. At weekly intervals, each sleeve was moved to a new branchlet, until the female died. The first three individual *H. pantherina* released into sleeves were checked after 4 days: all three females had survived, and eggs could be seen on the dorsal surface of several adult scales. No further assessment of this release method was made, because detecting *H. pantherina* eggs or young larvae in the field was difficult. In February 1994, 5000 beetles were released onto the gumwoods without sleeving. The rearing facility operated for 2 years until July 1995, when insufficient numbers of *O. insignis* could be found on St. Helena to maintain the culture of the predator. After the mass release onto the gumwoods, various other releases were made onto exotic ornamental plants at the request of private landowners. No parasitoids or other natural enemies of *O. insignis* were noticed in any of the field collections of the scale used in the rearing facility.

DISTRIBUTION OF *ORTHEZIA INSIGNIS* ON ST. HELENA

Monitoring was undertaken in stands of *L. camara* at 27 additional sites across the island in 1993 (Fowler 2003). At all these sites, *O. insignis* infestations on *Lantana camara* L. (Verbenaceae) were visually categorised as abundant, present (but not abundant), or absent. *Lantana camara* was selected because it is a common host plant for *O. insignis* found all over the island at all altitudes. In contrast, gumwood trees are only common at Peak Dale and at the new restoration plantings at Horse Point (Fig. 4).

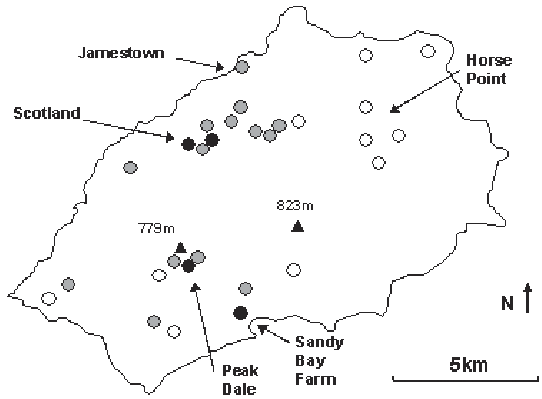

Figure 4. The island of St Helena. Circles indicate areas where the weed, *L. camara*, was checked for *O. insignis* infestations in 1993 (black = abundant scale; gray = scale present, but not abundant; open = scale not detected).

During May/June 1993, *O. insignis* was only abundant at Scotland (near to the main urban centre and only port at Jamestown), at Sandy Bay Farm and Peak Dale. This pattern of occurrence was consistent with *O.* insignis being a recent introduction onto the island, followed by accidental translocation to Sandy Bay Farm on cultivated plants, and then dispersal in the prevailing SE trade winds up to Peak Dale. *Orthezia insignis* was absent in the northeast part of the island and from many of the steep coastal cliffs in the south (Fig. 4). By February 1995, *O. insignis* had become abundant on *L. camara* at Horse Point, suggesting continued dispersal. Eggs and larvae of *H. pantherina* were seen in February 1995 on lantana about 1 km from a release site, demonstrating that the predator was also dispersing. The limited distribution of *O. insignis* in 1993 suggested that other *Commidendrum* spp., particularly the large recovering areas of scrubwoods (*C. rugosum* [Ait.] DC.) in the steep, dry coastal zone, might not have been exposed to the pest. Consequently, some simple investigations of the potential acceptability of several plant species endemic to St. Helena, including scrubwood, were undertaken in 1993 (see next section).

THREATS TO OTHER ENDEMIC PLANT SPECIES

Single cut shoots (10–15cm long) were taken from 2–9 plants each of *Lantana camara* and of 8 species of endemic trees and shrubs; gumwood, *C. robustum*; scrubwood, *C. rugosum*; bastard gumwood, *C. rotundifolium* (Roxb.) DC.; false gumwood, *C. spurium* (Forst.f.) DC.; he-cabbage tree, *Pladaroxylon leucadendron* (Forst.f.) Hook.f.; she-cabbage tree, *Lachanodes arborea* (Roxb.) B. Nord (all Asteraceae); St. Helena ebony, *Trochetiopsis melanoxylon* (Ait.f.) Marais; ebony/redwood hybrid, *T. erythroxylon* (Forst.f.) Marais x *T. melanoxylon* (Sterculiaceae). Fifty *O. insignis* nymphs were allowed to transfer onto each cut shoot from small pieces of infested lantana that were placed onto the cut shoots. The shoots, in vials of water, were positioned so that the foliage of each shoot was not touching anything. Remaining nymphs were counted after 3–4 days. The results are shown in Table 1. Mean survival of

O. insignis nymphs on the genus *Commidendrum* (gumwoods and scrubwoods) (Asteraceae) ranged from 34% for *C. robustum* to 70% for *C. spurium*. This was markedly higher than the 2.5% nymphal survival on the *Trochetiopsis* species (ebony and ebony/redwood hybrids).

Only the comparison of *Trochetiopsis* species/hybrid with *C. rugosum* and *C. spurium* was statistically significant. Given the suitability of *C. robustum* to *O. insignis* in the field, this result suggests that all 4 *Commidendrum* species were likely to be suitable hosts, but that the highly endangered *Trochetiopsis* species/hybrid in the family Sterculiaceae might be relatively much less suitable. The cut shoots probably deteriorated in the time required for scale nymphs to transfer from the drying pieces of *L. camara*, so even transfers to cut shoots of *L. camara* only had a 40% survival rate. Given the low number of replicates and high variability, little can be concluded about the suitability of the two species of cabbage trees (Asteraceae), although mean nymphal survival was 40% on the two replicates of he-cabbage trees, *P. leucadendron* (Table 1).

Table 1. Summarized results of the laboratory host range test, exposing cut shoots of selected endemic plants species in St. Helena to 50 nymphs of *O. insignis* for 3–4 days. The introduced weed *L. camara* was used as a control. Means followed by the same lower case letters are not significantly different. (Overall ANOVA on arcsin transformed data, $F_{8,29}$=4.66, P<0.01, comparison of means used Tukey HSD, P<0.05, SYSTAT [SPSS 1997]). Data from Fowler (2003).

Plant species	Replicates	Mean % survival (± SE)
Lantana camara	4	40 (±7.4)^{ab}
Gumwood, C. robustum	9	34 (±3.4)^{ab}
Scrubwood, C. rugosum	9	50 (±4.3)^{a}
Bastard gumwood, C. rotundifolium	2	50 (±15)^{ab}
False gumwood, C. spurium	2	70 (±5.0)^{a}
He-cabbage tree, L. leucadendron	2	40 (±10.0)^{ab}
She-cabbage tree, L. arborea	2	10 (±5.0)^{ab}
St Helena ebony, T. melanoxylon	4	2.5 (±0.8)^{b}
Ebony/redwood hybrid, T. erythroxylon x T. melanoxylon	4	2.5 (±1.3)^{b}

MONITORING PREDATOR/PREY ABUNDANCE AND IMPACT

Prior to 1993, the numbers of trees dying after infestation by *O. insignis* were counted, but infestation levels of the scale were not quantified. Nevertheless, the infestation levels were clearly very high as shown in Fig 1. In 1993 a monitoring program was started to relate scale infestation levels to damage or death of trees, and determine whether these measurements changed in response to increasing levels of the introduced predator. The two relict stands of gumwood trees at Peak Dale were designated sites A and B: site A being where infestations of *O. insignis* were first noticed in 1991, and site B being the stand approximately 0.5 km further to the south-west. At both sites, 15 trees were selected and labelled, with 5 trees in each of 3 visually assessed damage categories: severely infested (>50% of canopy affected); moderately infested (<50% of canopy affected); and uninfested. The selection of these 30 trees was as random as possible, although heavily shaded trees, and those with most of their canopy out of easy reach, were avoided. Gumwood trees have a simple, sparse canopy that was divided conveniently into approximately 20 cm long branchlets, comprising a group of 1–3 growing points, each with 10–20 leaves. Ten branchlets per tree were selected randomly and labelled for the non-destructive sampling program. At 1–3 month intervals, the numbers of adult and nymphs of *O. insignis* on each branchlet were visually estimated, and numbers of *H. pantherina* larvae and adults counted. The presence, or approximate percentage damage, due to other herbivores or predators was also assessed by eye. A visual estimate was made of the percentage of canopy of each tree that was heavily infested with scale.

The total numbers of dead gumwood trees at Peak Dale increased exponentially from 1991 to 1993–4 (Fig. 5). By 1995 mortality of gumwoods had reached an asymptote, with only 12% dead from a total of 2500 trees. If the exponential rate of loss of gumwoods from 1991 to 1994 had continued, all trees in the two relict stands at Peak Dale would have been killed by 1995.

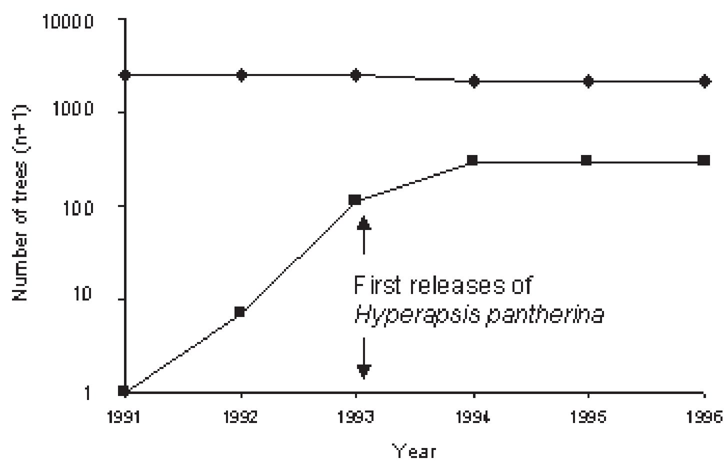

Figure 5. The numbers of live (♦) and dead (■) gumwood trees at Peak Dale, during the outbreak and subsequent biological control of *Orthezia insignis*. The exponential increase of the scale numbers from 1991 to 1993–4 was significant ($F_{(1,2)}$=66.3, P<0.05, r^2=0.97, log(y+1)=0.77x-1532, SYSTAT [SPSS 1997]). Data from Fowler (2003).

Mortality among labelled trees was highest at site A, and higher among trees that were severely damaged at the start of the release program (Table 2). However, all labelled trees became infested during the monitoring period, and mortality increased rapidly between 1993 and 1994 (Table 2) showing a similar pattern of tree death as the overall stand (Fig. 6). Mean numbers of *O. insignis* per 20 cm branchlet on severely infested trees peaked at over 3000.

The causative link between infestation by *O. insignis* and death of gumwood trees was visually obvious at the site, and is supported by data: the mean percentage of canopy infested with *O. insignis* on trees that were killed was significantly higher than on surviving trees (Fig. 7).

Data from trees in plots A and B, that were initially severely or moderately infested, were combined in Fig. 7. Data from the initially uninfested trees were excluded because *O. insignis* numbers mostly remained low. However, the numbers of *O. insignis* on the initially uninfested trees rose during the monitoring period, and then fell towards the end (as in initially severely and moderately infested trees).

Table 2. Cumulative mortality of gumwood trees at sites A and B in Peak Dale. There were 30 labelled trees, with five in each initial infestation category at each site. Dates were simplified to show numbers of trees dead at the end of 6-month periods, plus the final sampling date in February 1995. Data from Fowler (2003).

Initial Infestation Category	Site	June 1993	December 1993	June 1994	December 1994	February 1995	Total % Mortality
Severe	A	0	4	4	4	4	80%
	B	0	0	2	2	3	60%
Moderate	A	0	0	3	3	3	60%
	B	0	0	0	0	0	0%
Uninfested	A	0	0	0	1	1	20%
	B	0	0	0	0	0	0%
Total dead trees		0	4	9	10	11	37%

Figure 6. Mean (+/- SE) percentage of the tree canopy severely infested by *O. insignis* from 1993 to 1995. Trees that died had higher mean % canopy infestations by *O. insignis* than trees that survived (t = 4.62, df = 18, P<0.001, SYSTAT [SPSS 1997]). Initially uninfested trees were excluded as only one died. Data from Fowler (2003).

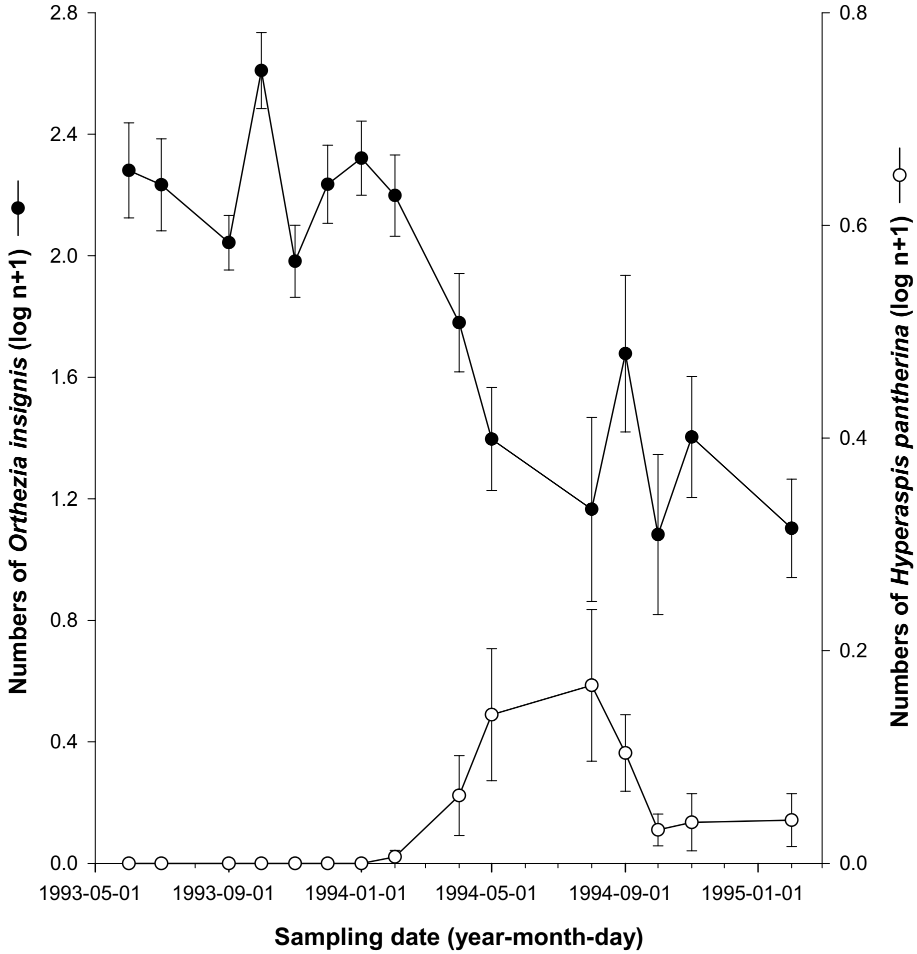

Figure 7. The mean numbers of *O. insignis* and *H. pantherina* on the labelled shoots of initially severely and moderately infested gumwood trees at Peak Dale. Error bars show the standard error for each mean, calculated on log-transformed data.

Data in Fig. 7 show an approximately 30× reduction in mean scale numbers per 20 cm branchlet, from >400 adults and nymphs (in September 1993) to <15 (in February 1995) when sampling ceased. The reduction in *O. insignis* populations was probably greater than this because monitoring staff overestimated scale numbers as the predator became common; in the field it was difficult to distinguish live scales from dead and partially consumed scales.

Numbers of *H. pantherina* counted on the labelled shoots were highly variable and usually low. High mean *H. pantherina* numbers were recorded occasionally on individual trees, in one case peaking at 1.3 adults and 3.4 larvae per 20 cm branchlet. The mean numbers of *H. pantherina* increased from January to August 1994, coinciding with the only consistent decrease in the mean numbers of *O. insignis* (Fig. 7). Earlier decreases in scale numbers might also have coincided with increases in predator numbers, but at this stage predator numbers were too low to be detected in the monitoring program.

Other herbivores detected in the monitoring program were limited to occasional lepidopteran larvae and mealybugs (*Pseudococcus* spp.). Few predatory arthropods, other than *H. pantherina*, were recorded: eggs of *Chrysoperla* species (Neuroptera: Chrysopidae) were found several times on gumwood shoots infested with *O. insignis*, but there was no evidence that the larvae were attacking the scale; one adult *Cheilomenes lunata* (F.) (Coleoptera: Coccinellidae) was collected from gumwoods infested with *O. insignis*, but did not attack *O. insignis* in confinement.

The relict natural population of St. Helena gumwoods, and probably related endemic species, were under severe threat from the alien scale insect, *O. insignis*. The number of dead gumwood trees increased exponentially from 1991 to 1993–4, and if this trend had continued, all the gumwoods in the two main stands would have been killed by 1995 (Fig. 5). Though speculative, this prediction is supported by the appearance of the gumwoods in February 1995: the foliage of most surviving trees in both sites showed very substantial blackening from sooty molds indicating that scale populations had been high and extensive (Fig. 8). There was also direct evidence from the abundance of exuviae and partly-predated scales that the densities of *O. insignis* had been high. It appeared that biological control had been successful only just in time to save most of the trees. The gumwoods were showing signs of recovery from the outbreak of *O. insignis*, with new growth appearing that was uninfested by the scale.

A number of factors contributed to the severity of the threat to the gumwoods from *O. insignis*. There were large numbers of alternative host plants for *O. insignis*, such as *L. camara*, around both sites. Hence, a decline in the numbers and/or health of the gumwoods was un-

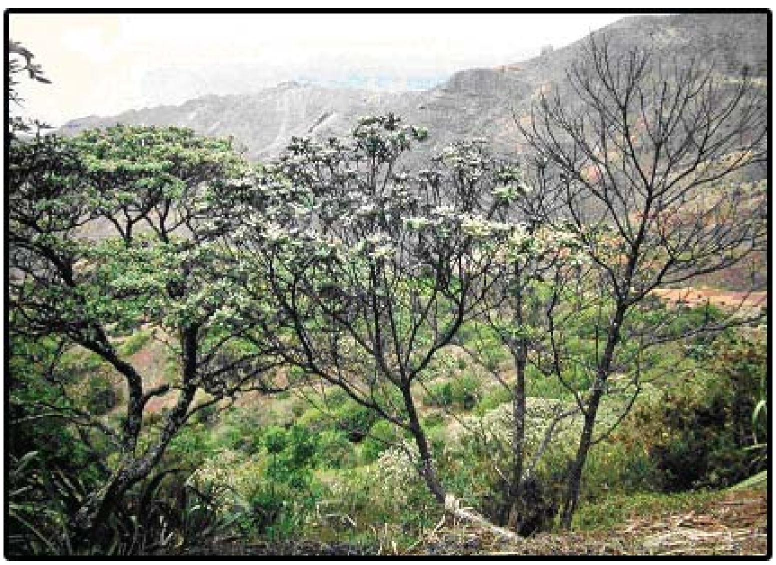

Figure 8. Surviving and dead gumwoods at Peak Dale in 1995. The central tree has uninfested regrowth emerging from leaves that are blackened by sooty molds. UGA1390011

likely to have limited scale numbers sufficiently to save any of the gumwoods at Peak Dale. It was also unlikely that existing predators or parasitoids on St. Helena would have suppressed *O. insignis*, as there was no sign of any mortality from natural enemies other than *H. pantherina* during the 2-year study. Finally, the gradual spread of *O. insignis* onto all of the initially uninfested gumwood trees, and the blackened appearance of most trees in 1995, gave little indication that any trees were less susceptible to the pest, and hence might have survived the outbreak.

Although the data in this study are only correlative, the success of *H. pantherina* as a biological control agent for *O. insignis* on St. Helena is consistent with its past record in Hawaii and Africa (Booth *et al*. 1995). Since 1995 there have been no further problems with *O. insignis* reported from St. Helena. Restoration projects, to encourage natural gumwood regeneration by controlling weeds in and around the two relict stands, can now proceed. These projects were considered pointless unless biological control of *O. insignis* was achieved (T. Upson, pers. comm.). A program to establish a millennium forest of gumwoods on a previously wooded site on the island began in 2000. Molluscs and lepidopteran larvae cause minor pest problems on these young trees, but *O. insignis* has not been noticed (I. Peters, pers. comm.), providing further evidence that the scale is under satisfactory biological control. The introduction of *H. pantherina* to St. Helena provides a particularly clear, quantitative study where the field population of a rare endemic plant was likely saved from extinction by biological control of an alien insect pest. Conservation benefits from biological control need to be considered in the current debate on the harm that introduced biological control agents can do to indigenous species (Howarth 1983; Louda *et al*. 1997; Simberloff and Stiling 1996)

ACKNOWLEDGEMENTS

G. Forrester provided statistical advice, and K. Alders helped sort the raw data. The Agriculture and Forestry Department (A & F), St. Helena, helped with many aspects of the project. A. Hill (A & F) managed the monitoring program. A. Cross, R. Mitchell and R. Shaw (CAB International) developed rearing methods in the UK, under license from the Ministry of Agriculture, Fisheries and Food (licence PHF 873A/667/73). A. Cross took the photographs for Figs. 3 and 4. P. Markham and I. Bedford (John Innes Institute) provided the culture of *O. insignis*. Funding was provided by the UK Government (ODA project OMC 92/94 349/053/001A).

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