Evaluating the presence of previously released biocontrol agents for the control of *Lantana camara* and *Opuntia* sp. on Ascension Island

DPL0038 – Biocontrol

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1. Summary

Ascension Island faces vast ecological challenges, with its highly degraded ecosystem dominated by invasive plant species, many of which are continuing to spread rapidly. The limited manpower available for control efforts makes the prospect of importing biocontrol agents, i.e., herbivores adapted as specialist feeders on problematic plant species, one of the only practical options for restoring some balance. At least six insect species have already been introduced for biocontrol, between the 1970s and 1990s, with other herbivorous taxa arriving through accidental imports. However, very little is known about the current extent of this new fauna, or the level of population regulation exerted on the various hosts. Only two of the deliberate introductions, both seed predators of Mexican thorn (*Neltuma juliflora*) were well-documented at the release stage, and only these have been subject to any follow-up monitoring. In this study, we report on a quick assessment of the current status of three of the remaining historical biocontrol releases: the cactus moth (*Cactoblastis cactorum*), which attacks prickly-pear (*Opuntia* species), together with two herbivores of lantana (*Lantana camara*), the lantana lacebug (*Teleonemia scrupulosa*) and lantana leaf-miner (*Uroplata girardi*). We surveyed a number of key populations of each host to determine the current spatial distribution of the agents and identified other herbivorous species that have been recruited alongside them. The level of control exerted by these assemblages was assessed. Key findings were as follows: -

Lantana camara

- A somewhat complex community of herbivores has accumulated, comprising at least 14 insect species and a plant mite.
- Lantana lacebug is one of the most widespread elements of this community, although densities were limited to a few individuals per plant in many areas. The largest populations were found along the dry, lowland edge of Lantana's altitudinal range in the Mars Bay area, where intense attack resulted in significant leaf bleaching.
- Lantana leaf-miner is still present on Ascension, but is now very localised, being found only at higher elevations on Green Mountain. Even here, it is mostly rare, but was common near the Marine Barracks. Only adults were detected during the survey in August, with no signs of larval mines.
- A further introduced (and economically damaging) pest, the jacaranda bug (*Orthezia insignis*), was the dominant herbivore at middle altitudes, particularly in the southeast of the island where it formed exceptionally dense infestations. These secreted large amounts of honeydew, on which a dense covering of black sooty moulds soon developed. From longer-term observations, it seems that their combined effect periodically results in heavy defoliation, although plant populations subsequently recover.
- Caterpillars of noctuid moths, also arriving through accidental introductions, were the main herbivores at higher elevations on Green Mountain. They are capable of consuming large amounts of foliage, though the damage may be sporadic. Only one larva was identified, as *Chrysodeixis acuta*, although it is suspected that other generalist noctuids may also be present.
- Other herbivores were rare, but several sap-sucking bugs were recorded alongside lacebug in the Mars Bay area. Most of the community is probably excluded by the more aggressive competitors at higher altitudes.

- Lantana continues to flourish on Ascension and maintains a wide distribution. However, it is quite possible that densities, and the rate of spread, have been limited to some extent by the high herbivory load.

Opuntia species

- There are two *Opuntia* species on Ascension Island**.** Drooping tungy (*O. monacantha*) is restricted to localised sites above 550 m elevation. No signs of catus moth were detected on this potential host, although it is difficult to determine whether the plant or the climate were unsuitable.
- Signs of cactus moth were almost ubiquitous on red tungy (*Opunitia elatior*), a widespread and sporadically common species from 200 to 500 m altitude across Ascension. It was clear that the biocontrol agent has established successfully.
- As cactus moth damage remains visible on the plant for many years, and larvae are difficult to find as they are mostly concealed in tunnels within the cladodes, determining the level of recent infestation is somewhat subjective. However, most patches showed some signs of active wounding and expelled frass. The density of infection was always moderately low.
- None of the sites visited had suffered sufficient damage to significantly impair the health of the tungy population. Recruitment from re-rooting of fallen pads was widespread, and plants were fruiting abundantly.
- The only other herbivores noted on *Opuntia* were Sternorrhynchan bugs that are well-known as catholic pests throughout the island: cotton cushion-scale (*Icerya purchasi*) and both armoured and soft-scale insects (Diaspididae and Coccidae). These were very sporadic and unlikely to significantly dampen the growth or survival of the host.

Whilst both lantana and red tungy are common and somewhat invasive on Ascension, neither currently appears to be spreading significantly. Opuntia and Lantana remain both widespread and Opuntia seems to recover well from the attack of its main control agent. However, the control agents seem to have led to an equilibrium where both species do not spread further (and more importantly do not seem to be highly problematic weeds, which is the main aim of any CBC). Sadly, the lack of background assessments before the release of the agents does not show whether the spread before the release was significantly worse. It is however known for both species to cause huge problems both environmentally as well as economically in areas where these control agents are missing. The level of regulation provided by herbivores may be contributing to their suppression to some extent, though further evidence would require more detailed population studies. Our study has not highlighted any particular concerns over the biocontrol methodology. Other invasive plants could thus be beneficially considered as high priorities for future active control programmes.

2. Introduction

2.1 *Plant invasions on Ascension*

It has long been recognised that oceanic islands are particularly prone to biological degradation (Loope et al., 1988; Simberloff, 2000; Thaman, 2002). Although humans often arrived relatively recently, they have rapidly exerted strong pressures over highly confined areas through deforestation, habitat change and the import of invasive species. The native communities, which evolved in isolation from many of the varied threats experienced in mainland regions, are considered to be highly vulnerable because they possess little adaptability to their changing environment.

Even by these standards, Ascension Island can be seen as a particularly extreme case. Soon after it was first charted by Portuguese mariners in 1501, the first wave of destruction was brought by the introduction of goats and rats, which inevitably multiplied rapidly and presumably browsed large amounts of the native plants (Ashmole & Ashmole, 2000). By the 1830s when Charles Darwin visited, the lowlands appeared to have been almost devoid of vegetation (Darwin, 1845). The British Navy eventually founded a permanent human settlement in 1816 (Hart-Davis, 2016), but immediately faced immense challenges, with few natural resources to rely on. A farm was soon established on Green Mountain, but even this struggled due to unpredictable weather, poor soils and limited water supplies.

The most dramatic transformations unfolded between 1843 and 1848, when an ambitious program of ecological engineering was attempted, under the encouragement of Joseph Hooker, John Lindley and other contemporary luminaries of the British scientific establishment. Their aim was to introduce new tree, shrub and grass species on a huge scale from other parts of the British Empire (Duffey, 1964; Hart-Davis, 2016). It was hoped that these would condense more moisture from the frequent mists enveloping the mountain summit, enrich the soils, and create the conditions for further growth and colonisation. The result was the importation of over 400 new species over just a few decades. Large areas of native vegetation were destroyed in the process, and new, somewhat incipient communities of non-native species began to occupy much of the terrain, exploiting vacant niches. Further waves of new colonisation took place throughout the late 19th and 20th centuries; in particular, the introduction of Mexican thorn (*Neltuma juliflora* (Sw.) Raf.) in the 1960-70s, which saw the lowlands re-vegetated with extensive savannahs. Over 90% of the plant species are now non-native, and it is estimated that only 0.01% of the land area remains as a stronghold for native habitats (Lambdon, 2023).

Whilst the new ‘ecosystem’ has been celebrated by some modern observers (e.g., Wilkinson, 2004), the changes also present severe problems (Lambdon et al., 2023). We only have an incomplete record of the original native flora, but it is clear that several taxa rapidly became extinct in the mid-1800s. Just seven endemic plant species now survive and all are extremely threatened, with all but one assessed as Critically Endangered on the IUCN red list (https://www.iucnredlist.org/). The main factors in the disappearances have been grazing or browsing mammals (sheep, rabbits, rats and mice), and intense competition from the numerous introduced plants. The developing non-native communities are species-poor and lack numerous functional groups that would normally be expected in a healthy ecosystem. Many of their most successful species are aggressive weeds that have proved problematic in other parts of the word, for example, Koster’s curse (*Clidemia hirta* (L.) D.Don), guava

(*Psidium guajava* L.), smokebush buddleja (*Buddleja madagascariensis* Lam.), spiked pepper (*Piper aduncum* L.) and whistling pine (*Casuarina equisetifolia* L.). These can create dense thickets that impede access, require regular clearance from sensitive areas, fuel rat populations by providing fruit, increase the risk of wildfire and sometimes favour unstable substrates prone to erosion or landslides.

2.2 *Biocontrol as a potential solution*

With a very small working population and limited budgets, Ascension has little capacity to address the problems posed by the massive scale of plant invasions. If the challenges are to be addressed, ecological solutions must play an important part in any management initiatives. Biological control could thus potentially be a key tool, as herbivores and pathogens play an important role in checking the vigour of aggressive plant species elsewhere in their ranges. In fact, the absence of such species living alongside introduced populations is considered to be a major factor facilitating their invasiveness: an idea that has been termed the "enemy release hypothesis" (Kean & Crawley, 2002). By importing specific pests known to attack targeted invasives, there is a hope of limiting their density and spread, reducing management costs and eventually even facilitating the development of a richer, more balanced ecosystem. It is increasingly recognised that complexity, with many interacting species imposing layers of regulation, often encourages greater ecological stability. Vandermeer et al. (2010) described how restoration of a complex food chain was able to provide robust and predictable conditions for coffee growing in Mexico, offering preferable outcomes to those achieved by conventional, pesticide-heavy agriculture.

2.3 *History of biocontrol on Ascension Island*

It is likely that deliberate biocontrol efforts date back as far as 1910 on Ascension, when the ladybird *Cheilomenes lunata* Fabricius was said to have been imported as a predator of aphids which were damaging crops on the Farm (Darlow, 2007). Unfortunately, there is little documented evidence of this initiative and the original source is unclear, although this and several other ladybird species (Coleoptera: Coccinelidae) are now well-established on the island. Since the 1970s, at least six intentional biocontrol agents have arrived, and a considerably greater number of species that exert biocontrol effects through herbivory on invasive species have reached the island as accidental imports, although the latter have received little attention and are thus imperfectly known. The vedalia beetle, *Novius cardinalis* Mulsant (Coleoptera: Coccinelidae) was brought as a predator of cotton cushion scale (*Icerya purchasii* Maskell) in 1976 (Darlow, 2007), and two specialist seed-feeders of Mexican thorn were imported in 1997, *Algarobius prosopis* LeConte and *Neltumius arizonensis* Schaeffer (Coleoptera: Chrysomelidae) by entomologist Simon Fowler (Fowler, 1998; Jewsbury, 2000). Sap-sucking insects such as psyllids, mirid bugs, and aphids were also found to be attacking Mexican thorn on Ascension and were thought to have been introduced accidentally from the Caribbean. The mirid bug of the genus *Rhinocloa* causes widespread damage and is thought to lead to substantial mortality of trees (White, 2009). A psyllid native to the Caribbean, *Heteropsylla reducta*, is present and is presumed to have arrived with plant material when Mexican thorn was introduced to Ascension. Currently, the general opinion is that these introduced herbivores – by causing substantial damage – have brought down levels of recruitment of new seedlings considerably. Mexican thorn is still expanding its range on Ascension albeit at a slower pace as these biological agents are insufficient to halt the spread alone (White, 2009). White recorded stunting from insects on 98% of trees sampled with 30% showing heavy dieback in 2009.

These psyllids were still found to be prevalent in new Neltuma growth during site visits conducted during the *Evippe* sp. #1 releases in April 2024. Although not known to be intentionally introduced, they are recognised, actively released biocontrol agents elsewhere and are likely to be having an impact on Ascension.

Whilst the use of Mexican thorn predators in biocontrol was somewhat experimental and driven by an urgent need to brake the progress of this rampant invader, the remaining agents were presumably brought because they had been trialled elsewhere with considerable success, and attacked species that were moderately abundant on Ascension at the time. The moth, *Cactoblastis cactorum* Berg (Lepidoptera: Pyralidae) is a specialist feeder on prickly pear, *Opuntia* spp. (Cactaceae), and two pests of lantana, *Lantana camara* L. (Verbenaceae) were also introduced: the lantana lacebug, *Teleonemia scrupulosa* Stal (Hemiptera: Tingidae) and the lantana leaf-miner, *Uroplata girardi* Pic (Coleoptera: Chrysomelidae). These three agents are the focus of the current study.

The concept of biocontrol is often regarded with mistrust by the general public, thanks largely to the relatively few but high-profile initiatives that have proved disastrous, such as the introduction of cane toads (*Bufo marina* L.) to northern Australia in 1935 to control sugar cane pests. The toads spread to become rampant predators on native fauna, and their toxic secretions also proved devastating to potential predators (Shine, 2010). It is however important to note that no scientists were involved in the release of the cane toads and that farmers without any understanding of the biology of the species were responsible for this. Such early releases may have been poorly-conceived, but science has learned from the mistakes and best practice is now much more rigorous (MacFayden, 1998), with an expectation of careful risk assessment during the scoping phase, followed by intensive host-range testing to ensure that there is minimum likelihood of ‘host-jumping’ onto ecologically important or threatened species in the new range.

Another essential element of well-planned programmes is detailed documentation of the approaches, and post-release monitoring at regular intervals so that establishment and spread can be tracked. This scrutiny is vital. It may be necessary to take some remedial action in the early stages in the unlikely event that unidentified ecological issues arise. But the converse is more probable: not all releases are likely to be successful, and repeated efforts may be necessary to ensure success. After considerable investment in developing such a programme, it would be economically and economically costly to leave open a risk of failure through a lack of attention. Over the longer term, monitoring to track the progress of the agent, and its effectiveness at achieving the desired control effect, can provide important lessons for future efforts. If the attempt fails, when and why did it do so? If the attempt is successful, can the methodology be improved, in a way that might be useful to the next project?

The careful approaches adopted by Simon Fowler provided a good attempt best practice, despite the limited scientific capacity of Ascension Island at the time. The initial releases were well-documented, and success was monitored after 3 years by a student, Nicholas Dewsbury. In 2010, another MSc student, Liza White, was able to conduct a repeat survey (White, 2009). Unfortunately, the remaining release events are shrouded in mystery, with almost no surviving record of the methodology and little data to indicate their success and failure. Although one of the Mexican thorn beetles, *Algarobius prosopis*, has established well and consumes large numbers of seed, the other, *Neltumius arizonensis*, is likely now extinct. It is quite possible that the vedalia beetle has also disappeared.

To address some of the gaps, this study has been undertaken to examine the current distribution and efficacy of the three remaining 1970s releases: *Cactoblastis cactorum*, *Teleonemia scrupulosa* and *Uroplata girardi*. All three species exist as part of a simplified ecosystem that is developing in complexity over time. They compete with other, accidentally-introduced pests which also exert some biocontrol effect on their host. Therefore, the survey has been expanded to also note the role played by wider herbivorous invertebrates on the target plants.

3. Study species

3.1 Host plants

Information relating to the study species was taken from the recently published book, 'Flowering plants & ferns of Ascension Island (Lambdon *et. al*., 2023).

3.1.1 *Lantana camara* L. (Lantana)

Figure 1: *Lantana camara* ©T. Hunt

Status: Invasive

Description:

A shrub, reaching 3 m in upland areas but low and spreading in dry places, often under 80 cm (Fig. 1). Stems slender, green or pale greyish-brown, 4-angled, furnished with small, sharp, backwards-pointing thorns. Leaves in pairs, ovate-lanceolate, up to 11 cm long, rough, coarsely hairy; margin serrate; odour sage-like, but rather foetid, dubiously likened to blackcurrants. Flowers unstalked, arranged in dense clusters, ~3 cm across, arising from the terminal leaf axils. Calyx membranous, 1.5 mm long, the rim truncate. Corolla with a slender tube, 11 mm long, spreading into a disk of 4 petals, 10–11 mm across; lateral petals rounded, upper and enlarged lower petals hammer-headed. Fruit a black, spherical, berry, 6 mm across, containing a single large, hard seed.

Distribution:

Occurs over most of the island except in the most barren places, from sea level to near the summit. The lowland form is prevalent from 250 to 550 m with the upland form beginning to dominate above 600 m. Native to the neotropics, from Venezuela to Texas and the Caribbean, but introduced around the world, mainly in the 19th century. Now ubiquitous in tropical regions and often a pernicious invasive.

Habitat:

In the lowlands, lantana frequents dry, rocky places, ashy hillsides and open guava scrub, but sometimes also occurs on clinker and lava, in pasture, and semi-arid shrubland (e.g., of

Juniperus, *Opuntia* or *Tecoma*). Upland populations often form thick, monospecific stands on slopes and in gullies, but may be more scattered amongst other dense invasives or in rank grassland.

Ecology:

Two distinct varieties occur on the island. Lowland plants have a yellowish-white corolla which turns pale pink after fertilisation. Upland plants are var. aculeatus, with a bright yellow corolla, turning dark pink with an extensive orange centre. Elsewhere, lantana (particularly var. aculeatus) can be a serious weed in pastures and natural habitats. The leaves contain an alkaloid, lantanin, which is toxic to livestock and may cause dermatitis on exposure to sunlight.

The species is a strong competitor on Green Mountain, choking some valleys, notably near Summerhouse Ridge. In the lowlands, infestations are rather more local, and rarely attain the densities achieved on St Helena. This appears to be largely the result of biocontrol efforts. Lantana lace bug, *Teleonemia scrupulosa*, and a leaf-mining beetle, *Uroplata girardi*, were released in 1973 (Darlow, 2007), but appear to have only a moderate impact. However, the accidental introduction of a feared worldwide pest, the jacaranda bug (*Orthezia insignis*), has been unexpectedly beneficial. Unusually, the species barely infects other species on the island, but lowland lantana populations are often densely infested and may be covered with black sooty moulds which feed on their excreted honeydew. Seed set is often reduced, and there is some indication that numbers have declined over the last decade. Stands on the SE plateau periodically suffer widespread and total defoliation.

History:

Remarkably, this ubiquitous invader was not recorded by either Duffey in the 1950s (Duffey, 1964) or by Packer in 1974 (Packer, 1983), although it must have been widespread by the latter date for biocontrol to be considered. Nevertheless, it has spread rapidly in the post-war years. At least the lowland variety was perhaps brought as an ill-advised garden plant, as this form is not present on St Helena: the most likely source of accidental introduction. The berries are edible to humans when ripe, but bear little flesh, and the corollas can be chewed for a sweet hint of nectar. Neither harvest provides much reward for the effort.

3.1.2 *Opuntia* spp.

Two *Opuntia* species are present on Ascension Island.

A) *Opuntia monacantha* Haw. (drooping tungy)

Figure 2: *Opuntia monacantha* © Phil Lambdon

Status: Naturalised

Description:

A densely shrubby cactus (Fig. 2) rarely reaching 5 m. Sometimes forming a stout, woody trunk armed with tufts of 20–40 long, sharp spines. Pads broadly ovate, thin, surface glossy, dark green. Areoles well-spaced; disc white-woolly, fringed by small, easily-abraded glochidia. Upper pad spines 1–2, unequal, yellow with a blackish-red tip, bleaching with age. Flowers with a stout receptacle, broadest near apex. Tepals are mitre-shaped, deep yellow, the outer slightly notched and with a broad, red central stripe. Stamens exceeding 400; anthers yellow. Style with ~6 stubby stigmas, pale yellow. Fruit 5 cm wide, bulbous, red when ripe but remaining green locally; areoles with numerous glochidia; flesh pale, watery, embedded with reddish-brown, globose seeds.

Distribution:

It is reasonably common along the Mountain Road, and spilling down to Middleton's Ridge. A few are also dotted across the slopes and side gullies of Breakneck Valley. Indigenous to S Brazil and neighbouring countries. Sporadically naturalised in the tropics, particularly around the rim of the Indian Ocean and parts of the Pacific. One of 3 species formerly named '*Opuntia vulgaris'*, resulting in much confusion over identity.

Habitat:

Rocky places, cliffs, rarely in mixed scrub (e.g. of *Leucaena*, *Eucalyptus*), 480–670 m.

Ecology:

Frequenting dry to sub-humid forest, coastal scrub or dunes in the native range. The distribution on Ascension probably reflects planting rather than ecology. Fertility is enhanced by out-crossing, and although the fruits develop they seldom ripen fully. It is not clear what proportion of the long-dormant seed is viable, but most regeneration is probably via rooting of fallen pads. The population could even derive from a single founder clone.

History:

Perhaps not arriving until the 1960s, though possibly much earlier since early *Opuntia* records gave little indication of species. Duffey (1958) and Packer (1974) made no mention; neither did Fairhurst (2004), but her photograph is clearly of this taxon. Formerly much grown in S Asia and Australia, where spreading rampantly to become a major nuisance. Introductions of *Cactoblastis* and cochineal have subsequently all but controlled it in many places. Useful for hedging and fodder. The fruit is edible but bland.

B) *Opuntia elatior* Mill. (red tungy)

Figure 3: *Opuntia elatior* © T. Hunt

Status: Naturalised

Description:

A large, shrubby cactus to 4 m (Fig. 3). Stem composed of flattened, ovate pads, furnished with fleshy, subulate leaves when young, but these soon fall. Areoles are whitish, felty, and densely armed with numerous cinnamon-coloured glochidia and several long, sharp, yellowish spines, fading to grey with age. Flowers unstalked, ~4 cm wide, arising from the pad margin; receptacle barrel-shaped, with many areoles, the spines reduced or absent. Tepals are mitre-shaped, in several whorls, the outer short, sepal-like, reddish-brown, the inner up to 2.5 cm, petal-like, pinkish-crimson. Stamens are numerous and pink. Stigma yellow, 5-lobed.

Receptacle enlarging to 5 cm long in fruit, ripening to dark red, glochidia persistent; flesh gelatinous, watery, red, studded with blackish, ovate seeds, ~6 mm.

Distribution:

It is widespread between 200 and 600 m, mostly as scattered individuals or saplings, but reasonable densities of mature shrubs occur in a number of areas, occasionally becoming almost impenetrable. The worst infestations are found in Cricket Valley, but others occur between Two Boats and Lady Hill, near Devil's Riding School, the Middleton's area, Dampier's Valley, along the NASA Road and on the flank of Goat Hole. Native to Columbia and Venezuela, perhaps also to the Lesser Antilles. A serious invasive on St Helena and sparingly naturalised in S Asia and southern Australia, but surprisingly little established elsewhere.

Habitat:

Arid, rocky places, occasionally intermixed with other shrubs, e.g. Mexican thorn, *Tecoma stans*. Though usually avoiding shade, it often forms an understorey to eucalypt woodland, and there is an extensive stand interspersed with *Casuarina* around the lower stretch of Portuguese Path.

Ecology:

An aggressive colonist that substantially modifies the surrounding habitat into dense yet unforgivingly dry scrub. The glochidia are highly irritant, penetrating skin at the merest touch and only painstakingly removed with tweezers. Flowering all year and fruiting abundantly, but also regenerating rapidly from fallen pads (even the areoles on the fruit root vegetatively). To arrest the spread, a moth, *Cactoblastis cactorum*, was introduced to Cricket Valley in 1973. The orange and black striped caterpillars hollow *Opuntia* pads from the inside, weakening if rarely killing the plant. Though hugely successful in Australia, the drab adults do not disperse far and infestations remain somewhat erratic. *O. elatior* was a serious problem in Malaysia in the 19th century but was brought under control by the release of another predator: the cochineal insect, *Dactylopius opuntiae*, a mealybug-like species prized by Ancient Meso-American cultures for the red dye it yields when crushed. It has yet to be trialled on Ascension, and deliberate introductions to St Helena in the 1800s did not persist. The Ascension population is occasionally prone to develop mutant limbs, where the pads are replaced by gnarled, cylindrical branches without spines. Rabbits may eat the pads during times of drought.

History:

Packer (1983) considered *Opuntia* to have been introduced by Wren from Madeira in 1847, but Lindley's report of the same year (Lindley, 1847) verifies that a few specimens were already growing in the Mountain garden. *O. elatior* is not widely grown on Madeira, and the earliest trials may have involved *O. ficus-indica* or *O. stricta*. The current species seems more likely to have arrived via St Helena, where established since 1813. Both Lindley and Hooker encouraged future propagation, extolling the virtues of the 'Indian fig' for fruit, cattle feed and binding soil. Ironically, *O. elatior* is of little value, being too unruly for hedging and with tasteless fruits. By the late 1850s, Bell mentioned "a great number of invasive prickly pears".

3.2 Biocontrol agents

3.2.1 *Cactoblastis cactorum* Berg (Cactus moth)

Figure 4: Adult *Cactoblastis cactorum* © Peggy Greb, USDA ARS

The following account has been summarised from Zimmermann et al. (2001). *Cactoblastis cactorum* (Fig. 4) is one of four moth species known to feed exclusively and voraciously on prickly pear cacti (Cactaceae: genus *Opuntia*). Despite the widespread distribution of the host genus across warmer parts of the Americas, the moth has a restricted natural range, native only to Argentina, Paraguay, Uruguay and southern Brazil. Although a few Brazilian *Opuntia* species are considered to be resistant to attack, it seems capable of breeding successfully in most species, with at least 24 hosts proven to be acceptable.

Elsewhere, breeding typically takes place during the winter months, but 2-3 generations can develop each year under good conditions. Egg clutches are laid on the surface of fresh pads (cladodes) in a raised cluster. The boldly red-and-black striped larvae hatch en masse and collectively chew a single entry-hole through the epidermis, encountering some difficulty evading the sticky sap. Once they have successfully penetrated the tissues, they tunnel through the internal parts of the cladode whilst they feed and grow, for 2-4 months depending on temperatures. Eventually, they exit and drop to the ground where they pupate amongst litter. The somewhat drab adult moths generally do not disperse far, but in areas where *Opuntia* is sparsely-distributed they have been recorded travelling up to 24 km in search of new hosts.

The first use of *Cactoblastis* in biocontrol took place in SE Australia between 1925 and 1934, in an attempt to salvage vast areas of cactus-infested rangelands. The effort was extremely effective. Much of the 24 million hectares of heavily-invaded land was returned to grass or agriculture, with densities decreasing by up to 90% in some areas. However, the scale of the operation was massive, involving the distribution of over 750 million eggs. In one detailed survey, it was estimated that approximately 25 million *C. cactorum* larvae had been required to kill off one hectare heavily infested *O. stricta*.

After efficacy had been proven, further releases were attempted in other parts of the world: firstly, in South Africa, then New Caledonia, Hawaii, Mauritius, the Caribbean Islands, Pakistan and Kenya. It successfully established in most areas, but in South Africa spread was irregular and in Kenya and Pakistan it appears to have failed. From the Caribbean, it has been accidentally introduced to Cuba and Florida, from where it has spread across southern USA and Mexico and is threatening native *Opuntia* populations.

Cactoblastis was introduced to St Helena in 1971, where dense infestations of *Opuntia ficus-indica* L. and *O. elatior* cover large areas of arid coastal slope (Ashmole & Ashmole, 2000). It established successfully but with relatively little impact at the population level on either host species. Larvae were presumably taken from St Helena to Ascension soon after, but there is little surviving information on when or where the releases occurred. Neither is it clear how extensive the infestations were at the time.

3.2.2 *Teleonemia scrupulosa* Stal (Lantana lacebug)

Figure 5: Lantana lace bug © CINHP_G. McCormack

Lantana lacebug (Hemiptera: Tingidae) is found naturally throughout the range of its host, extending from Paraguay and northern Chile to Mexico and southern USA (https://entnemdept.ufl.edu/creatures/beneficial/lantana_lace_bug.htm). In the wild, the species is almost exclusively found on *Lantana camara*. In feeding tests, it has been shown to attack other lantana species, but with a greatly reduced efficacy (Reinert et al., 2006), although where introduced it has occasionally been recorded to host-jump onto somewhat distantly related species. In India, releases were halted due to concerns over infestations in commercial teak plantations (*Tectona grandis* L.f.), and in Hawaii it has colonised a native shrub, *Myoporum sandwicense* A.Gray (Verma, 1999; Hight et al., 2004).

The life history has been described by Dhiman & Sangeeta (2008). Adult females (Fig. 5) insert eggs into the undersides of the leaf veins. Infected parts soon brown and curl, but the nymphs emerge within 2 weeks. They feed by injecting saliva through their stylets and subsequently sucking-up the partially digested mesophyll tissues. Numerous nymphs and adults may be present on any one plant simultaneously, and with heavy infestations the plant soon becomes bleached where dotted with numerous tiny white feeding holes. These tissues eventually brown and die. Younger leaves and flower buds are favoured; thus, in severe cases the bugs can effectively render the host sterile by preventing the reproductive organs from maturing.

The apparent host-specificity of wild populations made *T. scrupulosa* a good candidate for use as a biocontrol agent against an extremely problematic global weed. The first releases were trialled in Hawaii around 1900 (Hight et al., 2004). It has subsequently been widely introduced, to Fiji, Australia, Indonesia, island groups in the Pacific, India, Mauritius, and various parts of Africa (Davies & Greathead, 1967). It was imported to St Helena in 1971-72 and is still present (Key et al., 2021), although the efficacy of control has not been assessed. According to Darlow (2007), it arrived on Ascension Island the following year, no doubt as a result of a deliberate biocontrol attempt, although little else appears to be known about the initiative.

In general, the level of control achieved across the introduced range has been modest, but severe local defoliation and partial control are often observed and the species is thus considered as a useful addition to the community of insects attacking lantana (Davies & Greathead, 1967).

3.2.3 *Uroplata girardi* Pic (Lantana leaf-miner)

Figure 6: Lantana hispid © CINHP_G. McCormack

As with the previous species, Lantana leaf-miner (Fig. 6) is native to the southern part of the host range, encompassing southern Brazil, Paraguay and northern Argentina (Broughton, 2000). It was identified as a highly host-specific candidate for biocontrol based on surveys, and subsequently introduced to Hawaii in 1961, where it has proved to be the most effective of several agents trialled (Broughton, 2000). Some studies have found it to be extremely restricted in preferences, even to the extent that different populations are adapted to specific lantana cultivars and temperatures (Cilliers & Nesser, 1991). However, from laboratory tests conducted on Trinidad, Bennett & Maraj (1967) recorded some feeding on *Lippia* species (Verbenaceae), teak and two further *Lantana* species (*L. montevidensis* (Spreng.) Briq. and *L. trifolia* L.). Of these, larvae only developed successfully on *L. trifolia*, and suffered much higher mortality rates than on *L. camara*.

The life history has been reported by Bennett & Maraj (1967). Eggs are laid singly on a leaf. When the larvae hatch, they tunnel into the mesophyll where they feed, forming slender, sinuous mines. After 20-35 days, they pupate, remaining within their gallery. The leaf gradually curls and browns, but not until the adults have emerged. These survive for a further 1-2 months, and continue to feed on the leaf margin. Heavy infestations can remove a significant volume of foliage, and thus markedly impair plant growth. In some regions, generations continue throughout the year, but in others there is reported to be a diapause during the winter (Cilliers & Nesser, 1991).

Following the successes in Hawaii, *U. girardi* was introduced to various other regions: the Marianas Islands in 1963, Fiji and Tonga in 1969, South Africa in 1974, New Caledonia in 1977 and the Solomon Islands in 1993. It has also reached northern India (Muniappan & Viraktamath, 1986). In New Caledonia, the beetles spread at least 10 km within two years, and were reported to exert considerable mortality on lantana stands (Gutierrez & Forno, 1989). On St Helena, a population appears to have been introduced at the same time as lantana lacebug (Ashmole & Ashmole, 2000), and was presumably also brought with it the Ascension Island the following year. It is still widespread on St Helena with leaf mines visible in the majority of Lantana stands.

4. Field survey methodology

The AIGCFD had maps available of *Lantana* and *Opuntia* sp. sites (Lambdon & Darlow, 2008) therefore we could select a range of sites across the species full distribution of Ascension (Fig. 7).

(a) (b)

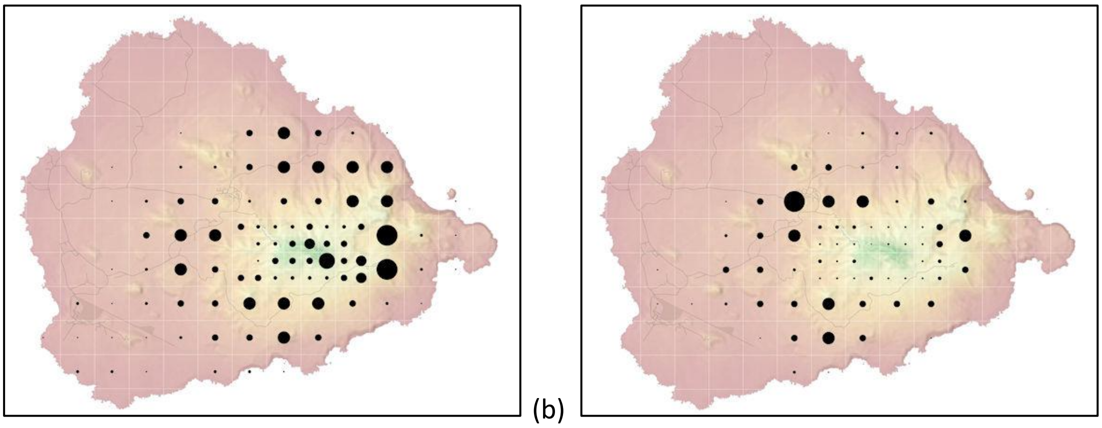

Figure 7: (a) & (b) *Lantana camara* and *Opuntia elatior*. distribution across Ascension (Lambdon *et. al.*, 2023)

Table 1: Sites surveyed as part of this study

Locations	*Lantana camara*	*Opuntia* sp.
Marine Barracks	X	
Elliot's Path	X	
Red Lion	X	
Mountain Road		X
North East Cottage	X	
Dampier's Drip Path		X
Portuguese Path	X	X
Bear's Back	X	
Grazing Valley	X	
NASA Site	X	
NASA Straight	X	X
Cricket Valley	X	X
Traveller's Hill		X
Two Boats settlement		X
'God Be Thanked' water tank	X	X
Mars Bay	X	

Sites (Table 1) were surveyed for approximately 20 – 30 minutes by walking around and inspecting a number of individual plants for signs of insect infestations until it was felt that coverage was representative of the population. Each species detected was assigned an invasiveness score, based on a very general six-point scale designed to allow a rapid comparative assessment, regardless of the varying levels of aggregation and feeding patterns of different taxa (Table 2). Any unknown species were sampled and identified as far as possible in the laboratory under a microscope. The distribution of each species was mapped using QGIS (Open Source Geospatial Foundation, Oregon, USA).

Table 2: A broad assessment of the Level of Invasiveness of each species was completed under a six-point scale

LEVEL OF INVASIVENESS	
0	No signs of the BCA (no impact)
1	Only a small proportion of host plants show signs of the BCA (low impact)
2	A high proportion (>25%) of plants show signs of the BCA but damage low (< 10% of leaves or stems show damage) (medium impact)
3	A high proportion (>25%) of plants show signs of the BCA and damage is significant (> 10% of leaves or stems show damage) (medium impact)
4	The majority of (>50%) of plants show signs of the BCA but damage overall low to medium (on average < 20% of leaves stems show damage) (high impact)
5	The majority of (>50%) of plants show signs of the BCA and damage overall high (on average > 20% of leaves stems show damage) (high impact)

5. Results and discussion

5.1 *Lantana camara*

Seventeen insect species were collected from *Lantana camara* (Table 3). A species of ensign fly (Sespidae) was recorded displaying on the foliage on Green Mountain, but since this family almost exclusively feed on decaying vegetation, they are purely commensal and thus not relevant to the discussion of biocontrol. Similarly, ladybird larvae (Coleoptera: Coccinellidae) of the species present in Ascension Island are predatory on Sternorrhyncha species and therefore only important through the regulatory impact they may have on herbivorous species.

Table 3: Level of Invasiveness per invertebrate found on *L. camara*.

Family	Species name	Common name	Number of sites	Mean score
Order Trombidiformes (super-order Acariformes)				
Unidentified	Unidentified sp.[1]	Plant mite sp.	1	0.08
Order Diptera (Class Insecta)				
Chloropidae	*Siphunculina striolata* Wiedmann		1	0.08
Sepsidae	Unidentified sp.	Ensign fly sp.	1	0.08
Hemiptera (sub-order Heteroptera)				
Lygaeidae	*Nysius* sp. Dallas	Seed bug sp.	1	0.17
Pentatomidae	*Thyanta* sp. Stål	Shield bug sp.	1	0.08
Tingidae	*Teleonemia scrupulosa* Stal	Lantana lacebug	12	1.92
Order Hemiptera (sub-order Sternorrhyncha)				
Aphididae	*Myzus ornatus* Laing	Ornate aphid	1	0.08
Aleyrodidae	Unidentified sp.	Whitefly sp.	1	0.08
Diaspididae	Unidentified sp.	Armoured scale sp.	1	0.08
Ortheziidae	*Orthezia insignis* Browne	Jacaranda bug	8	2.00
Pseudococcidae	*Planococcus* sp.?	Mealybug sp.	1	0.08
Psyllidae	Unidentified sp.	Jumping plant louse sp.	1	0.08
Order Lepidoptera				
Noctuidae	*Chrysodeixis acuta* Walker	Tunbridge Wells gem	1	0.08
Noctuidae	Unidentified sp.[2]		5	1.08
Order Coleoptera				
Chrysomelidae	*Uroplata girardi* Pic	Lantana leaf-miner	2	0.25
Coccinelidae	Unidentified sp. (larvae only)	Ladybird sp.	2	0.25
Curculionidae	*Alceis longimanus* Fabricius		2	0.17

[1] Not a spider-mite (Tetranychidae), which has proved to be widespread and damaging pests elsewhere on Ascension.
[2] Presence only betrayed by feeding damage and frass.

Impact of invertebrates observed on *Lantana camara*:

1. Lace bug (*Teleonemia scrupulosa*)

Lace bug has been quite successful and is now well-established across most of Ascension, but generally at low densities. Considerably the highest abundances occurred at Mars Bay, where the impact on lantana was often severe. Plants are thinly scattered amongst lava outcrops at this site, but it is not clear whether the population was directly reduced through herbivory; the habitat may also have been marginally suitable, as Mars Bay is particularly dry and on the lower edge of the altitudinal range of lantana on Ascension (<100 m above sea level). The trend suggests that lacebug may thrive best at low altitudes, either as a result of higher metabolic rates at increased temperatures, or because climatic stress may have made the plants more susceptible to feeding (e.g. by lowering the ability to invest in secondary chemical defences). However, the reliability of this geographical pattern is difficult to assess as there are few other sites at comparable elevations where lantana is represented by more than very occasional individuals. Shrubs scattered along Elliot's Path (at approximately 740 m above sea level) were also sometimes infested moderately heavily, which suggests that the influence of climatic conditions on behaviour is not simple.

Another possible explanation for site-to site variation is related to the presence of different genotypes. *Lantana camara* seems to be represented by at least two distinct varieties on Ascension: an 'orange-yellow flowered' (probably var. *aculeata*) and a 'pink-yellow flowered' form. The first of these is predominantly restricted to upland areas, whereas the second is prevalent up to 550 m. There is a degree of uncertainty along the boundary zone where phenotype can be difficult to distinguish. Reinert et al. (2006) found considerable variation in susceptibility to lacebug infestation between different cultivars; in general, those with orange/red flowers were much more vulnerable than all others, with 'pink-yellow' forms experiencing intermediate damage. As Mars Bay is populated by the 'pink-yellow' form, Reinert et al.'s trend is opposite to that found for Ascension. However, the authors noted that flower colour was unlikely to be the key driver of the preferences, and their results could merely be taken as evidence for differences in varietal susceptibility.

At most sites, lacebug herbivory was unlikely to have exerted much pressure on lantana populations as densities were generally limited to a few individuals per plant. Even on Elliot's Path, the foliage did not display strong signs of bleaching, leaf curl or other damage. However, as a mobile pest with a rapid, iteroparous life-cycle, it is possible that infestations could fluctuate considerably over time, and may thus build-up sporadically to much higher numbers on occasions. Due to a limited study time-frame we were not able to examine temporal changes in numbers or distribution, but this would be a valuable avenue of further research.

2. Lantana leaf-miner *(Uroplata girardi)*

This Chrysomelid beetle has been considered a highly promising biocontrol agent in many other regions (Gutierrez & Forno, 1989; Cilliers & Nesser, 1991; Broughton, 2000). It is still surviving on Ascension, but seems to be very local in distribution now, and is probably restricted to high altitude sites on Green Mountain. The original release sites were presumably in more accessible areas at much lower elevations, so poor dispersal is unlikely to be the reason for the limited range, which may be more closely linked to climate and perhaps to host genotype.

Although the population around the Marine Barracks is quite dense, we did not see any signs of leaf mines caused by the larval stage during the survey visit in August. The only possible explanation is that the life-cycle is strongly seasonal, and that we visited only after the latest generation had emerged as adults. However, lantana leaves remain on the plant for a number of months, and it is surprising that no galleries were visible on at least the older foliage. The beetle, if present, should be fairly to detected through the leaf mines and they remain visible even in seasons when no active feeding takes place or when adults are present. Infected foliage had presumably dropped rapidly, but as most of the infested plants were relatively healthy, the impact of the herbivores seemed to be minimal. Furthermore, the beetle was apparently absent or at low densities across other parts of the Mountain.

3. Jacaranda bug (*Orthezia insignis*)

Figure 8: Heavy infestation of Jacaranda bug, NASA Site © C. Visser

Jacaranda bug is a noted pest species across the humid tropics and some warm-temperate areas (CABI, 2021). On St Helena, it was responsible for causing deaths of the threatened gumwood (*Commidendrum robustum* (Roxb.) DC.: Asteraceae), until a ladybird, *Hyperaspis pantherina* Fürsch (Coleoptera: Coccinellidae), whose larvae are specialist feeders on Ortheziidae, was imported as a biocontrol agent in 1993, achieving satisfactory levels of population regulation (Fowler, 2004). *O. insignis* is often considered to be a particular pest of lantana, but as the St Helena example demonstrates, it can be somewhat polyphagous and has been noted from a wide range of plant families, including infestations on important crop plants, e.g., coffee (*Coffea arabica* L.: Rubiaceae), sweet potato (*Ipomoea batatas* (L.) Lam.: Convolvulaceae), *Citrus* spp. (Rutaceae), aubergine (*Solanum melongena* L.: Solanaceae), and rose (*Rosa* spp.: Rosaceae) (Gupta et al., 2019). On Ascension, it is certainly most common on lantana, but can also form sporadically-heavy infestations on *Tecoma stans* L. (Bignoniaceae), and is occasionally found on Asteraceae species, particularly *Ageratum conyzoides* L. (pers. obs. P. Lambdon, 2024).

O. insignis has a high rate of population multiplication. Adult females lay both parthenogenetic and fertilised eggs in a conspicuous rectangular ovisac carried around on the abdomen, with the progeny only released once they have hatched as nymphs. According to Epila (1986), the hatchlings take approximately 42 days to reach maturity, although timing probably depends on host and climate. Only the males are winged, so autonomous spread is reliant on plant-to-plant contact, or occasional accidental transference (e.g., via broken branches spread by the wind). Nevertheless, jacaranda bug colonies were widespread on even isolated plants at appropriate altitudes. They are undoubtedly tended by ants which ‘farm’ them for honeydew, and much of their migratory ability is probably via deliberate transportation by the workers. A number of ant species are present on Ascension, and collectively they are extremely abundant across the island. The ants also defend their colonies from predators.

During our survey, *O. insignis* was mainly found at sites from mid-altitudes upwards, although it was also reasonably common on the isolated northern lantana population on Bear’s Back at only 200 m above sea level. This was a more significant population when the original botanical survey of Ascension was conducted in 2008 (pers. obs., P. Lambdon), and many of the original larger plants are now dead. The decline is likely partly attributable to jacaranda bug: even in 2008, many of the plants were densely covered in sooty moulds (see below). However, an extreme drought between 2017 and 2021 is also likely to have played a part in the demise.

O. insignis reaches extremely high infestations on the SE plateau around 500 m altitude (i.e., near the NASA Site and Cricket Valley), where it is by far the major pest species (Fig. 8). Black, powdery sooty moulds (caused by ascomycete fungi, primarily of the genus *Cladosporium* but also sometimes by *Alternaria* and other genera) develop on the copious honeydew excreted by the jacaranda bug, and these may completely coat the plant, presumably restricting photosynthesis. In some cases, the stress caused by the combined effect of the attack causes complete defoliation. Whilst not particularly evident during the limited window of the survey, extensive areas of lantana are sporadically rendered leafless during wet winter periods (e.g., in August 2021). At this higher-elevation, the plants do not seem to suffer mortality and new foliage generally springs back within weeks (pers. obs., P. Lambdon, 2008-2024).

Where reaching high densities, *O. insignis* clearly exerts a strong biocontrol effect and, even if not killing the host, appears to curtail growth and reproduction to some extent. Despite this, lantana remains a dominant species in areas around the NASA site. It is less common further down the slopes to the east and in Cricket Valley, probably in part because it is outcompeted by other vigorous shrubs. The toll of herbivory is likely to be partly responsible for the modest levels of invasiveness observed across many middle altitude areas, although it is difficult to confirm the population-level effect without dedicated studies. At higher altitudes, *O. insignis* is much less common, and the red-yellow cultivar of lantana may form dense and very vigorous stands in some valleys of Green Mountain.

4. *Lepidoptera* spp.

At the higher altitude sites, many lantana plants were observed to suffer heavy leaf damage, with large parts of the lamina consumed between the veins, often leaving the lower epidermis intact. In the worst areas, individual plants showed signs of predators on almost all leaves. It proved difficult to find the insects responsible, presumably because they had matured or pupated by the time of the survey, or because they retreated from the leaves when not feeding (perhaps active only at night). The species responsible were almost certainly large larvae, and the most likely culprits were noctuid moth caterpillars (Lepidoptera: Noctuidae). At least 14 common global pest species from this family are present on Green Mountain (Robinson & Kirke, 1990). All are highly polyphagous, and attack a wide range of plant families. We only found one example in the act of feeding, and this was identified as *Chrysodeixis acuta* Walker. However, other species could be contributing to the damage.

Based on the quantity of foliage removed, such caterpillars have the potential to exert a substantial impact on lantana, though their abundance is likely to be highly variable over time and between sites. At a location only a few metres from the Marine Barracks lantana patch, another noctuid, *Spodoptera littoralis* Boisduval, was observed to almost totally destroy a stand of nettle (*Urtica urens* L.) and part of an angel's trumpet tree (*Brugmansia arborea* (L.) Sweet) over a matter of a few weeks. Lepidoptera thus appear to be the principal herbivores of lantana on upper parts of Green Mountain. However, due to the host's ability to recover from sporadic damage (as noted for *Orthesia insignis* above), such an inconsistent effect, even if intense, is unlikely to greatly impact long-term population survival.

5. Other species

All of the other species we found were probably common on a range of different hosts, but occasionally feed on lantana as well. At Mars Bay, *Nysius* (Lygaeidae), shield bugs (Pentatomidae) and the chloropid fly *Siphunculina striolata* (whose larvae mine the leaves of various plant species) were relatively common but did not cause substantial damage compared to lace bugs. There is some chance that *Nysius* exerted a significant negative effect on plant reproduction, as they target developing fruits and flowers. Since these tissues form only a small part of the plant, even small pest populations may be damaging. However, the lantana appeared to be flowering reasonably well, and as the fruits are hard, they are probably relatively resistant to sap-suckers. The weevil *Alceis longimanus* (*Curculionidae*) was present, but could occasionally occur anywhere on the island. We found single specimens of a whitefly, psyllid bug and a plant mite, although were unable to identify any of these. The most common generalist pest species on Ascension are Sternorrhynchan bugs such as mealybugs and scale insects; however, with the exception of *Orthezia insignis*, we recorded almost none on lantana except for one area infested with aphids (*Myzus ornatus*) near the Marine Barracks.

Implications for *L. camara*:

Based on the number of 1 × 1 km grid cells occupied, lantana is only the 14th most common species on Ascension Island. It is considerably more abundant on St Helena, where it ranks 1st using the same criteria (Lambdon, 2012). One of the reasons for the differences in performance may be the drier climate of Ascension. Although a similar herbivore fauna is present on both islands (Ashmole & Ashmole, 2000), it is also possible that their impact has been more significant locally. This particularly seems to apply to *Orthezia insignis*, which reaches spectacular concentrations around the SE plateau. Despite its desirable effect, *O. insignis* remains a potential danger to other elements of the flora due to potentially devastating impacts and the well-documented ability to infect a wide range of other hosts. Introduction of the predatory ladybird *Hyperaspis pantherina* could be considered to limit the risk, as has proved successful on St Helena. However, due to the relatively few native plants currently found in the hotspot areas, and the valuable regulatory impact on lantana, such a measure may be better held in reserve, pending a future change in circumstances.

In contrast, we found little evidence to suggest that the two deliberately-introduced biocontrol agents are particularly significant in limiting their host's abundance, except perhaps along the driest lowland margins of the range. Nevertheless, it is difficult from a single survey to get a full picture because pest levels probably change throughout the year and in response to climatic events, including heavy rainfall.

The survey has revealed a complex system developing between lantana and its dependent herbivore community, with several accidentally-introduced pests recruited to the fauna in addition to the two biocontrol agents released in the 1970s. It seems likely that this system remains in a state of flux, but the current distribution of its members is affected by multiple factors, including optimum climatic envelopes, interactions with ants (which may be symbiotic or aggressive), the spatial arrangement of host plants (influencing the ability to migrate between patches), and direct competition between community members. It seems likely that competition is a major factor. Under humid, productive conditions on Green Mountain, large, aggressive noctuid caterpillars consume much of the available foliage before other herbivores can access resources. The rapidly multiplying *Orthezia insignis* is able to dominate at intermediate altitudes, where aided by prolific colonies of ants. In these areas, both *Teleonemia scrupulosa* and *Uroplata Girardi* remain somewhat marginal.

Although lantana remains a widespread weed on Ascension, and the fact that there is a wide range of additional control agents available, including pathogens which would all be safe to use and easy to obtain, we would not recommend introducing new biocontrol agents in the short-term, simply because:

1. There are already some pests exerting control.
2. Lantana is not a major problem at the moment, except in certain parts of Green Mountain.
3. There are other species which are more of a priority to control.

5.2 *Opuntia* sp.

Impact of invertebrates observed on *Opuntia spp.*:

Most of the insect damage on *Opuntia* seems to be due to *Cactoblastis cactorum*, although many plants were infested by small areas of cotton-cushion scale and white scale insects (Table 4). We were unable to identify the scale insects to species level, but both long-bodied soft-scale species (belonging to the family Coccidae) and circular armoured-scale species (Diaspididae) were sporadically present, with perhaps more than one species of each observed. Several scales of both groups are known to be present on a wide range of plant species on Ascension (Supple & White, 2013), and a more complete list is currently in development (pers. Comm, Adam Sharp, 2024). In no cases did we find sufficient amounts of scale to significantly impair plant health, but a few plants had moderately large infestations of Diaspididae. The presence of ladybirds is associated with these minor pests, as their larvae are predators of Sternorrhyncha (especially mealybugs, Pseudococcidae, but probably most of the local introduced fauna).

Table 4: Level of Invasiveness per invertebrate of *Opuntia* spp.

Family	Species	Common name	No. of sites	Mean score
Order Hemiptera (sub-order Sternorrhyncha)				
Monophlebidae	*Icerya purchasii* Maskell	Cotton cushion scale	1	0.17
Coccidae	*Pulvinaria* sp.	Soft-scale	3	0.5
Diaspididae	Unidentified sp.	Armoured-scale		
Pseudococcidae	*Planococcus/Pseudococcus* spp.	Mealybug	1	0.17
Order Lepidoptera				
Pyralidae	*Cactoblastis cactorum* Berg	Cactus moth	11	1.17
Order Coleoptera				
Coccinellidae	*Cheilomenes lunata* Fabricius	Lunate lady bug	1	0.17

Figure 8: *Cactoblastis cactorum* visible on cladodes © C. Visser.

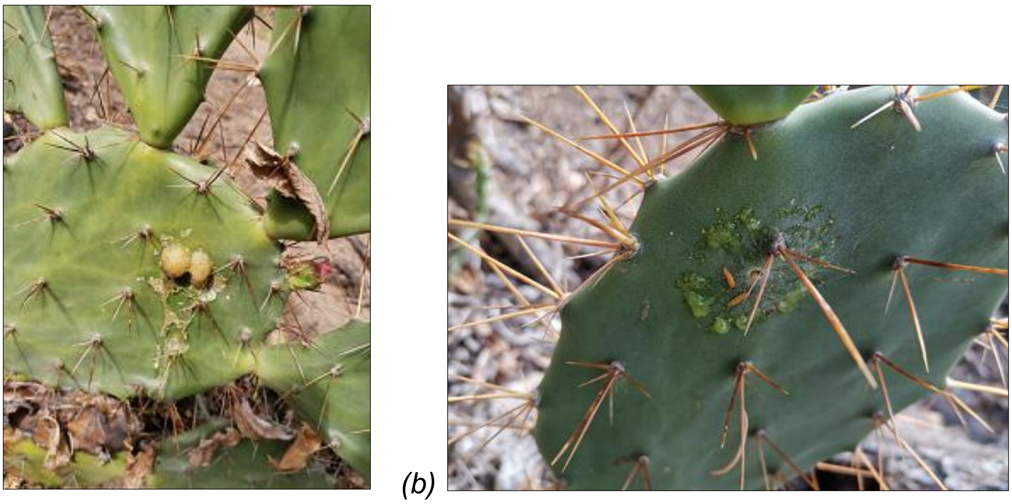
(a) (b)

Figure 9: (a) Fresh sap and frass visible on cladode. (b) Larvae feeding on cladodes © C. Visser.

The abundance of *Cactoblastis cactorum* was difficult to measure because old damage is very persistent (remaining for years, even after the pads become woody). Verifying active presence relies on determining whether damage is recent, which can be difficult without dissecting tunnels through the green cladodes to find the larvae. Otherwise, the caterpillars are rarely seen unless migrating between cladodes (Fig. 8). However, leaking sap or fresh frass expelled from wounds around tunnel mouths gives a reliable indication of fresh activity (Fig. 9). We did not detect any adult moths, which are somewhat secretive, although further studies would be useful to determine the seasonal patterns of activity in the population. It was notable that the exceptionally large tungy populations around Portuguese Path appeared to be very little affected by *Cactoblastis*, despite a reliable and continuous host presence. Seasonal fluctuations cannot be responsible, because the lack of wounds on woody pads indicate that infestations have been historically low for at least a decade.

Unlike *Opuntia elatior*, there was no damage to the more local *O. monacantha*, providing some indication that the latter species may be an unsuitable host. However, *O. monocantha* has mainly been planted on Green Mountain above 550 m, and displays almost no altitudinal overlap with *O. elatior* which is restricted to areas below 500 m. It is thus possible that the cooler, more humid climate limits the range rather than host suitability. Relatively little has been reported elsewhere on the interaction between *O. monacantha* and *C. cactorum*, perhaps partly because cochineal insects, especially *Dactylopius opuntiae* Cockerell (Hemiptera: Dactylopiidae), have already provided effective control of this species in Sri Lanka and South Africa (de Souza, & Hoffmann, 2015; Humphries et al., 2022). The first *Cactoblastis* introduced to Australia for biocontrol were brought from Argentina where they were said to have been reared on *O. stricta* and *O. monacantha*, but since *O. monacantha* does not occur in the wild in Argentina, the source may have been misidentified (Varone et al., 2012).

Implications for *Opuntia*:

Although there are signs of *Cactoblastis* damage almost everywhere *O. elatior* occurs, the agent is probably causing relatively little impact, as cactus stands are often large and apparently reproducing healthily, whether via the copious fruits or the fallen pads, which re-root prolifically from even small fragments. Wounding is extensive, but we found little sign of secondary infection by diseases that may have further weakened the plants. Such effects are often important underlying causes of mortality from insect herbivory (Ingram & Robertson, 1999). It is certainly possible that the vigour and rate of spread of the population has been slowed, and since small saplings could be more vulnerable to destruction by an aggregation of larvae, sapling mortality could play a role in limiting recruitment. However, the true impact of such relatively small effects could only be understood through dedicated population studies.

Opuntia elatior is currently much less invasive than on St Helena (Lambdon, 2012), and reports from the 1800s suggest that it was not only then more extensive on Ascension but considered one of the island's major pests. In a letter to his successor (c.1922-25), Head Gardener Hedley Cronk noted that "prickly-pear threatened to become a grievous nuisance", and that the government had purchased a chemical known as the "Jansen process" to control it (unpublished document held by the Ascension Island Museum archives). Whether the subsequent decline coincided with the release of *Cactoblastis cactorum* is unclear.

There are potentially other biocontrol agents that have proved effective elsewhere, especially cochineal insects (*Dactylopius* spp.), and these could be considered for possible release on Ascension, but it would be difficult to justify the expense in the near future, because:

1. *Opuntia* is not a major threat at the moment, except perhaps in very specific cases where it may be growing around fence lines or buildings. The range does not appear to be expanding.
2. There are other species which are more of a priority to control.

6. Conclusion

All three introduced biocontrol agents have become successfully established, and (from our very limited assessment) we did not encounter any problematic ecological consequences of their presence, particularly to native flora or fauna. This may be viewed favourably when assessing the potential for future releases of biocontrol agents on other species. It is not clear whether any of the three, however, are critical in limiting the spread of their host, although other accidentally introduced agents seem to have been more effective. We cannot properly assess the level of regulation as there is still insufficient data to show how the populations have changed as a result of the pest impact. In future biocontrol programs, we recommend that it is critical to implement effective monitoring procedures in order to evaluate establishment and success.

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Annexures

<u>Annexure 1: Sampling methodology</u>

Sampling methodology - *Lantana camara*				
Date	**Location**	**Species present**	**Comments**	**Level of Invasiveness Score**
12/09/2023	GM Marine Barracks	*Uroplata girardi* (lantana, hispid)	Multiple present	**3**
		Alceis longimanus (Cureulionidae)	1	**2**
		Teleonemia scrupulosa (Lantana lacebug)	Multiple present	**3**
		Myzus ornatus (Aphid)	1	**2**
		Nymph of *Orthezia insignis* (Jacaranda bug)	1	**2**
12/09/2023	Mars Bay fire trucks	*Nysius* (*Lygaeida*)	7	**3**
		Siphunculina striolata (possible *Chloropidae*)	Multiple present	**2**
		Alceis longimanus	1	**2**
		Pentotomidae (Shield bug)	2	**2**
		Adult lacebug	Multiple present	**5**
21/09/2023	NASA building	Adult jacaranda bug	Multiple present	**6**
		Adult lacebug	Multiple present	**3**
		Juvenile lady bug	1	**2**
24/10/2023	GM Red Lion	Adult lacebug	2	**2**
		Uroplata girardi (lantana, hispid)	1	**2**
		Heteropsylla reducta (psyllid)	Multiple present	**2**
	God be Thanked tank	Mealy bug	Multiple present	**2**
06/12/2023	Bears Back	Adult lacebug, juvenile lacebug, adult lady bug	Multiple present	**3**
21/09/2023	NASA Road (upper)	Jacaranda bug	Abundant	**6**
	NASA Road (upper)	Lacebug	Occasional	**3**
30/01/2024	Cricket Valley (upper)	Lacebug	Very little present	**2**

	Cricket Valley (upper)	Jacaranda bug (*Orthezia insignis*)	Abundant	**3**
	Cricket Valley (upper)	Caterpillar frass		**2**
	Cricket Valley (upper)	Scale insects		**2**
	Cricket Valley (lower)	Lacebug		**3**
	Cricket Valley (lower)	Jacaranda bug (*Orthezia insignis*)		**6**
	Cricket Valley (lower)	Caterpillar frass		**3**
11/02/2024	Portaguese trial	Jacaranda bug	More common on the bottom end than the top	**4**
		Lace bug	Few on all the plants	**2**
	Along the track to NE Cottage	Lace bug	Couple on each plant	**2**
		Caterpillar damage	Can't find caterpillar, plants heavily defoliated	**5**
12/02/2024	Grazing Valley	Lacebug	Quite common, but doesn't seem to cause much damage	**3**
		Worm (*Chrysodeixis ipsilon*?)	Substantial damage	**4**
		Jacaranda bug	Saw some individuals	**3**
		Psylid (couldn't ID)	One individual	**2**
		Plant mite	One individual	**2**
12/02/2024	Elliots	Lace bug	Loads present	**4**
		Jacaranda bug (little amount present)	Little amount present, does not cause much damage	**2**
		Worm (*Chrysodeixis ipsilon*?)	Substantial damage	**4**
		Fly (*Sepsidae*)	Number of individuals present on one plant	**2**

Sampling methodology - *Opuntia* sp.				
Date	**Location**	**Species present**	**Comments**	**Level of Invasiveness Score**
12/09/2023	Dampiers	Frass; *Icerya purchasii* also seen; some fruits with scale (possibly *Pulvinaria* spp.), lady bug spp., mealybug sp.	Whole clump, orange in colour	**3**

12/09/2023	Travellers Hill (close to swimming pool)	*Cactoblastis* caterpillars; scale (possibly *Pulvinaria* spp.)	Multiple present; cut open a cladode to expose - could clearly see light green colouration against the light once we knew what we were looking for	**3**
22/09/2023	NASA	Signs of some predation	Can see light green pathways but difficult to ID without cutting cladodes open	**2**
24/10/2023	GM road	None present	Cut one cladode open to see if biocontrol is present	**1**
	GM road	None present		**1**
	Dampiers	Signs of some predation, but no *Cactoblastis* present		**3**
	Two Boats road	Signs of *Cactoblastis*; found biocontrol agent		**3**
	Road past school	Signs of *Cactoblastis*; found biocontrol agent		**3**
	NASA road	Signs of some predation, but no *Cactoblastis* present		**2**
06/12/2023	Centre of Two Boats	Signs of *Cactoblastis*, frass and found juvenile form of biocontrol agent	Can see light green pathways, frass and some juveniles present	**4**
30/01/2024	Cricket Valley (upper)	Little signs of *Cactoblastis*	See green pathways through cladodes	**2**
	Cricket Valley (lower)	Multiple stands; little signs of Cactoblastis, but *Opuntia* also covered with Guava trees	Some green pathways can be seen on some cladodes	**2**
11/02/2024	Portaguese trial	*Cactoblastis* signs present (frass present, not very common)	Very little damage and quite old - could be low as middle of summer	**2**
		Scale insects (light brown)	Most plants have them	**3**

Annexure 2: Map of *Lantana camara* occurrence

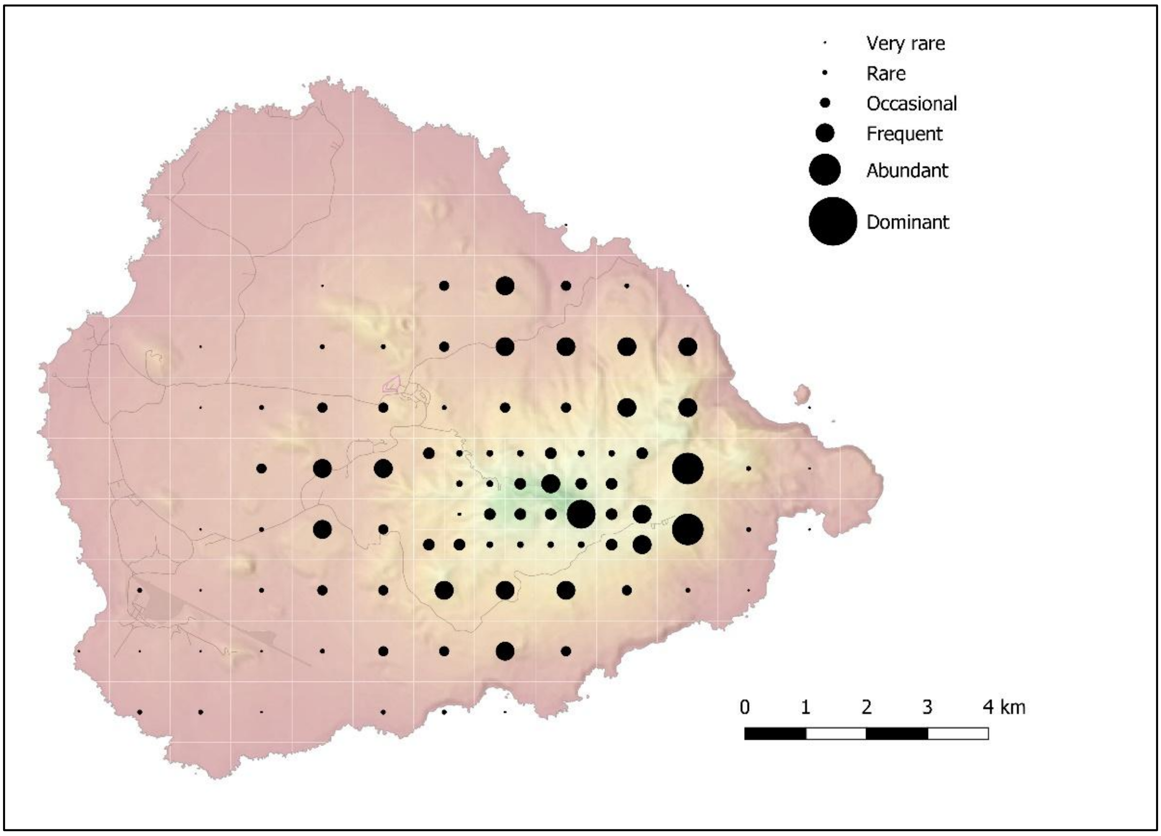

Figure 1: *Lantana camara* occurrence (*Lambdon et. al., 2023*)

Annexure 3: Maps of *Opuntia* spp. occurrence

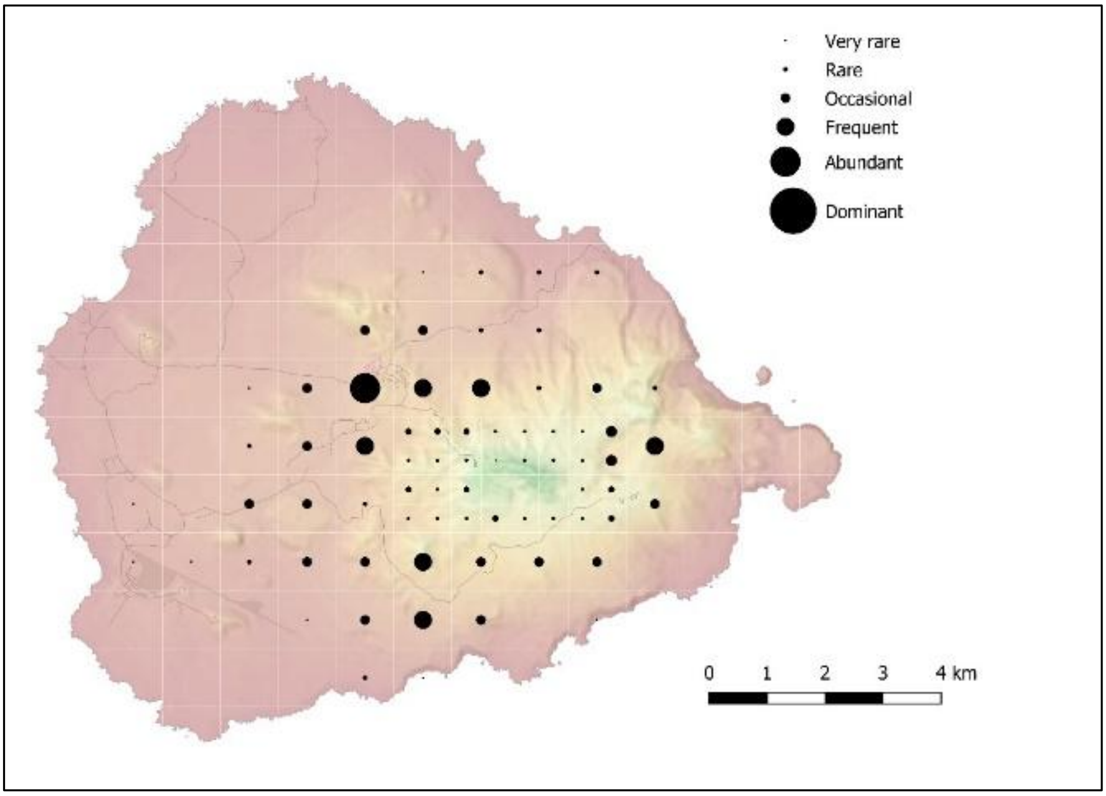

Figure 2: *Opuntia elatior* occurrence (Lambdon *et. al*., 2023)

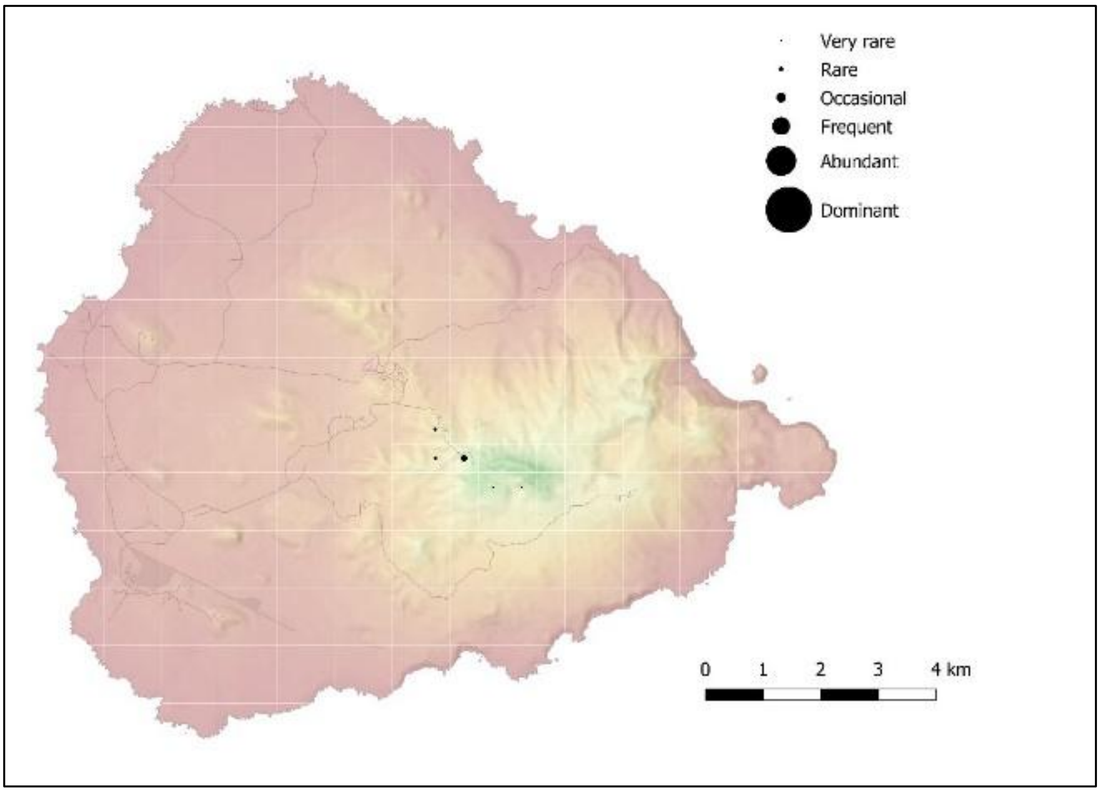

Figure 3*: Opuntia monacantha* occurrence (Lambdon *et. al.*, 2023)

Annexure 4: Maps of invertebrate presence on *Lantana camara*

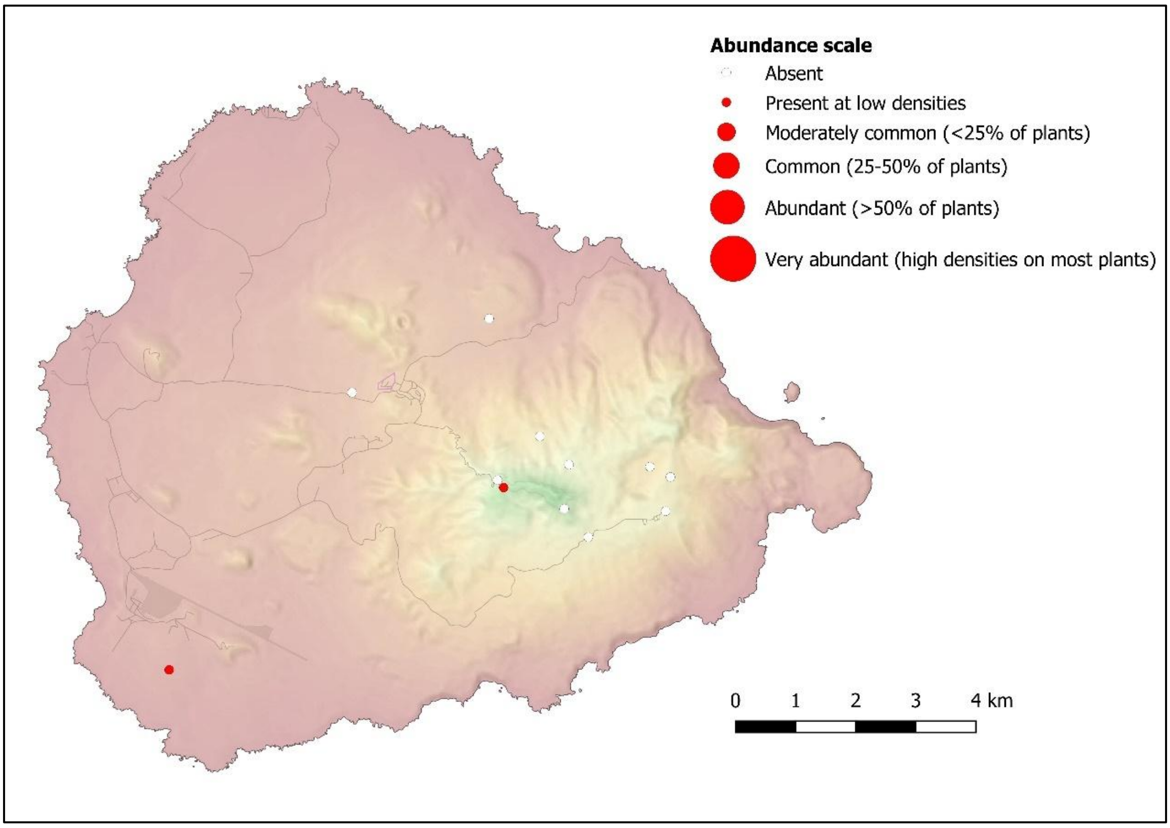

Figure 4: *Alceis longimanus* © C. Visser & P. Lambdon

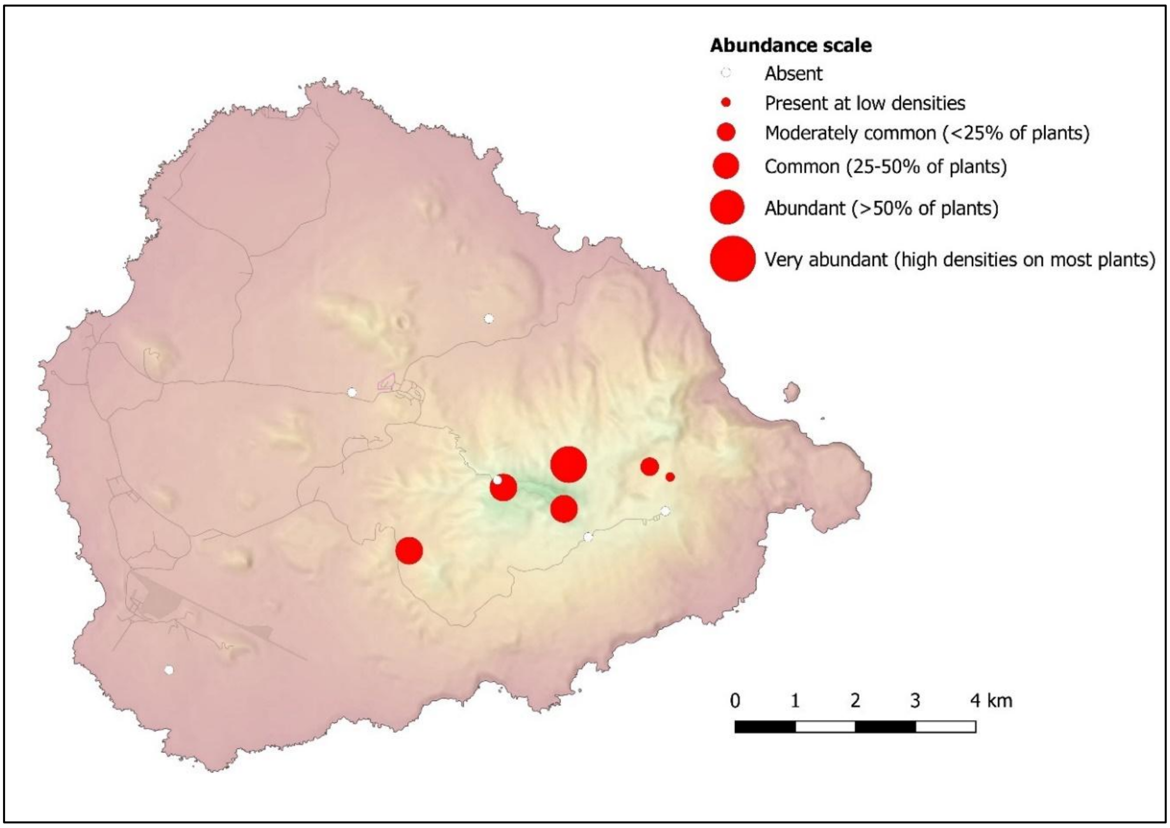

Figure 5: Caterpillar sp. © C. Visser & P. Lambdon

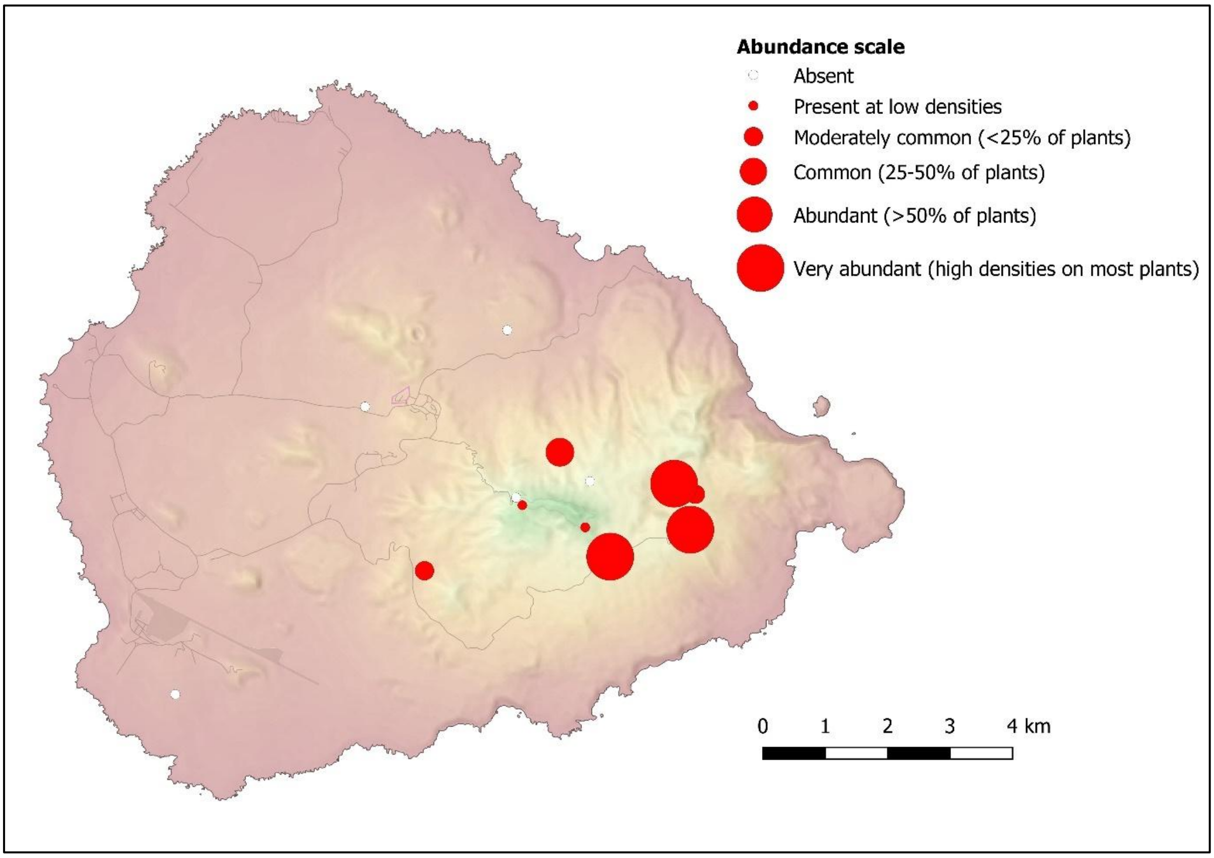

Figure 6: *Orthezia insignis* © C. Visser & P. Lambdon

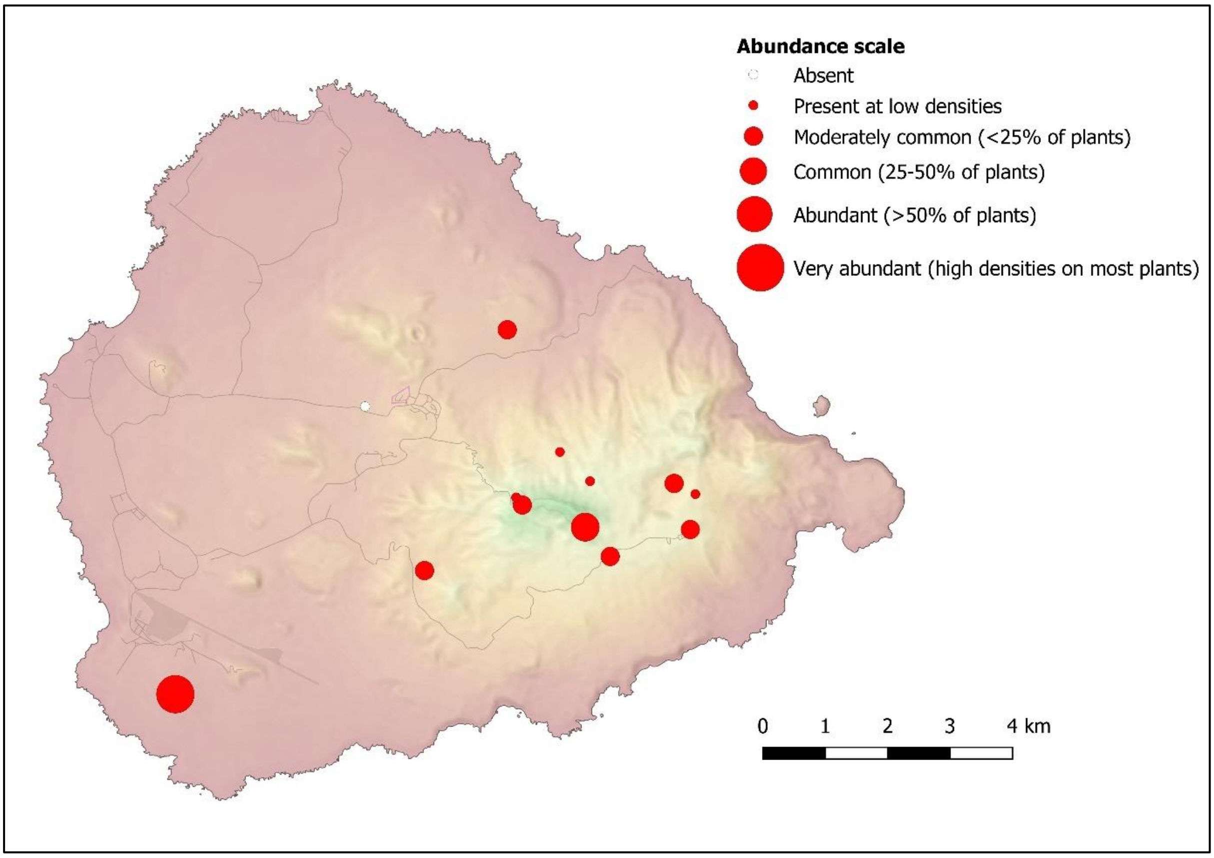

Figure 7: *Teleonemia scrupulosa* © C. Visser & P. Lambdon

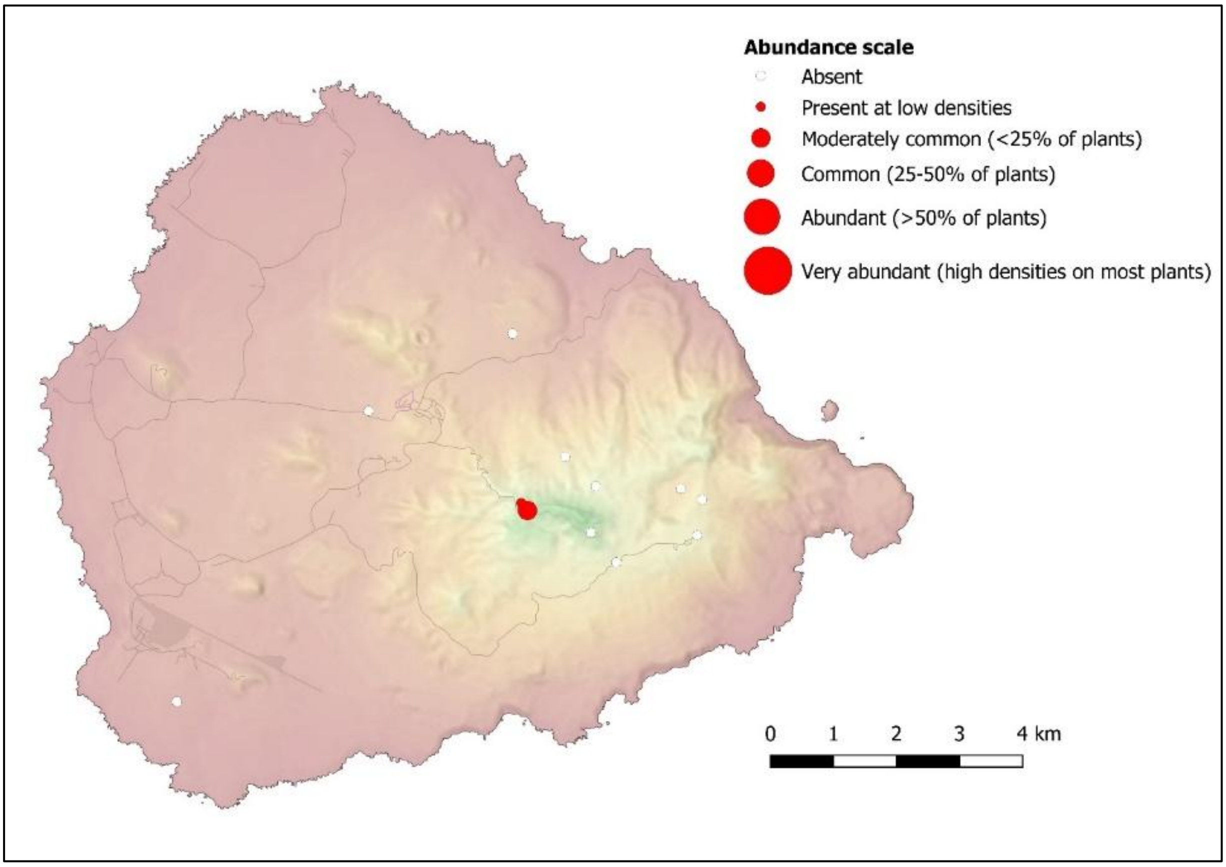

Figure 8: *Uroplata girardi* © C. Visser & P. Lambdon

Annexure 5: Maps of invertebrate presence on *Opuntia* spp.

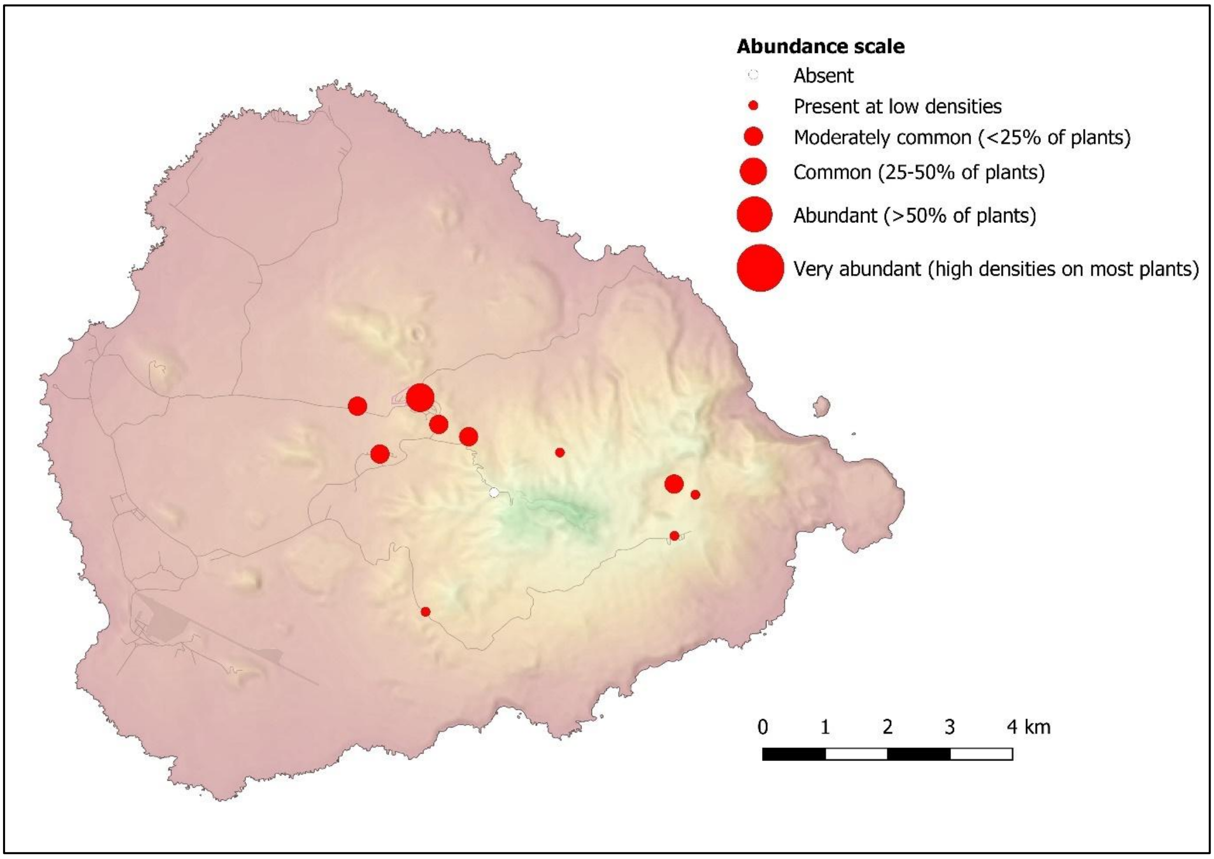

Figure 9: *Cactoblastis cactorum* © C. Visser & P. Lambdon

Annexure 6: Photos of *Lantana camara* infestations

(a)  (b)  (c) 

Figure 10: (a) & (b) Leaves show signs of predation. (c) Lace bugs are visible on the *Lantana camara* we surveyed © A. Hornett and C. Visser.

Figure 11: Jacaranda bug and sooty mould visible on *Lantana camara* surveyed near the NASA road © C. Visser.

<u>Annexure 7: Photos of *Opuntia* sp. infestations</u>

(a) 

(b) 

Figure 12: (a) & (b) It is difficult to determine the current effects of *Cactoblastis cactorum* as old damage is persistent © C. Visser

(a) 

(b) 

(c) 

Figure 13: (a) Clear signs of *C. cactorum* hollowing the cladode. (b) Signs of *C. cactorum* are present. (c) Cotton-cushion scale as seen on the fruit of *Opuntia* plants © C. Visser