South Atlantic Invasive Species Project

Botanical Survey of Ascension Island and St. Helena 2008

A report on the current state of plant invasions, and their implications for conservation and management

New Zealand flax
Phormium tenax

Mexican thorn
Prosopis juliflora

Phil Lambdon & Andrew Darlow

Vegetation monitoring in the South Atlantic

Needs and benefits

The U.K. Overseas Territories are home to unique and fragile environments, globally important for biodiversity and critical to the economies and quality of life of the local inhabitants. In many ways, the small South Atlantic islands of St. Helena and Ascension epitomise these facets better than any of the other territories. For a number of reasons, it is therefore particularly important that their biodiversity is assessed adequately, and changes monitored, so that threats can be recognized and understood at an early stage.

From an international conservation perspective, the extreme isolation of St. Helena and Ascension has lead to the evolution of unique floras and faunas. Ascension is geologically young (only around 1 million years old), providing relatively little time for species to establish and evolve, so that there are, for example, only 6 surviving endemic higher plants (Cronk, 1980). In contrast, St. Helena has a large number of species found nowhere else (around 45 surviving endemic higher plants: Cronk, 2000). Although the small size of the island means that it is often overlooked in global floristic analyses, the high proportion of endemics per unit area necessitate that it has a strong claim to be classified amongst the world's biodiversity hotspots (Hobohm, 2003). Furthermore, the endemic floras and faunas of St. Helena and Ascension are now extremely rare, and the unique native communities in which they occurred are heavily fragmented and degraded. Many are already included on the IUCN red list of the world's endangered species, and others which have not yet been formally-assessed are urgently awaiting inclusion. The overseas territories as a whole contain the overwhelming majority of the globally threatened species for which the U.K. has responsibility e.g. 90% of bird species (Sanders, 2006) and perhaps 95% of plants (inferred from Oldfield, 1999). The list of extinctions to date is already a notorious litany of disaster, an alarming sign of how small islands are impacted rapidly and acutely by the environmental problems which threaten the world as a whole.

In comparison with the flora and fauna of mainland U.K., the conservation of these rare species has been substantially neglected in the past. Very little may be known about the ecology of even some of the most critically-endangered. A greater understanding is necessary to develop appropriate methods of establishing domesticated populations, rehabilitating stock into the wild and restoring good quality habitat in which they can thrive. Even more critically, the current sizes and distributions of populations may remain poorly-known. This type of basic data is essential in order to prevent further losses. Since the last detailed, documented observations on St. Helena's endemic plants, made in the late 1980s/early 1990s (Royal Botanic Gardens Kew, 1993a), it seems that many have drifted closer to extinction. For example, the large bellflower, *Wahlenbergia linifolia*, previously known from only two locations but considered stable, is now reduced to a global population of just 20-30 small plants, subject to hybridisation and growing on unstable cliff ledges where it could be eradicated by land slippages (pers.comm. L. Malans, 2009). Only urgent, last ditch efforts can now prevent total extinction, but the seriousness of the situation was not appreciated until very recently due to lack of ongoing assessment. Only with a programme of regular monitoring and appropriate management strategies, will it be possible to recognize such declines and arrest any deterioration.

Conservation will play a vital part in the commercial future of St. Helena and Ascension as the development of tourism plays an increasingly central role in their economies. A unique natural heritage, with endemic species forming an important focal point, is amongst the islands' key assets. With economies diminishing and the need to diversify towards new sources of income, the rapidly-growing ecotourism sector offers the promise of sustaining at least some of the deficit. However, ecological issues have far wider implications, both natural and human. It is a stark fact that native species now constitute a tiny proportion of the total species number. Large numbers of alien introductions have become widely established which dominate much of the land area (Vitousek, 1988). They now form the bulk of the semi-natural ecosystems, often comprising communities which have been assembled from species originating in diverse parts of the world. The ecology of these new, developing, plant and animal communities, and how they are changing over time, remains little known, yet is important if they are to be managed in a way which will maximize their value to the island and its people.

Invasive species may have positive benefits, e.g. in preventing erosion, providing fodder for livestock, and food for pollinating insects. They may also become troublesome weeds which require costly control. Where invasive aliens such as whiteweed (*Austroeupatorium inulaefolium*) and Mexican thorn (*Prosopis juliflora*) have already become well established, they may necessitate several decades and considerable manpower to eradicate, or ongoing lower level effort to manage, with sustained impacts on farmers and other land users. It is generally considered to be much more cost effective to eradicate small populations of aliens soon after their arrival before they become well established, but this requires an organized "early warning system" to detect and assess the potential threat. In extreme cases, this type of measure can rescue livelihoods and save ecological devastation, but may be dependent on prompt action.

Predicting the threat posed by an introduced species is notoriously difficult. Even the best systems used to screen potential high risk introductions have a low rate of success due to the complexity of factors which determine invasiveness. Where species have become locally well-established, eradication may already to prohibitively expensive, and yet focused management of the problem could still ultimately prove to be more cost efficient that doing nothing and allowing the species to spread further. In such cases, ongoing monitoring can offer the only realistic compromise strategy; if the threat is not exacerbated over time then no further action need be taken, but if the species continues to expand its range, and/or increase in numbers, then further expenditure to control it may be a very worthwhile investment.

The current state of knowledge

The native flora of St. Helena has been reasonably well-studied in the past, and reasonably good accounts exist as far back as the early 1800s (Beatson, 1816; Cronk, 1984). However, even these were not written until 300 years after the discovery of the island, during which time the large-scale deforestation, extensive grazing by livestock and widespread introductions had already substantially and irretrievably changed the island. Although, more recently, Quentin Cronk has attempted to reconstruct details of the early habitats (Cronk, 1989, 2000), we have only a few chance historical references and early if very incomplete collections such of that of the Cook Expedition in the 1770s to provide glimpses of what the pristine environment of the island might have been like. Melliss (1875) suggested (although with little direct evidence), that up to 200 native plant species may have already disappeared without ever having been recorded. Far less attention has been given to the introduced species, and no recent, comprehensive species list has been compiled. The account of John Charles Melliss, published in the mid 19th Century (Melliss, 1875), is perhaps the most detailed and provides a useful picture of the flora of the day. However, little further work occurred until the 1970-1980s, when two privately-published reports were produced by R.O. Williams (1970) and L.C. Brown (1982). Both have limitations. Williams's list comprises both wild and cultivated garden plants, but frequently does not differentiate between the two categories. Although a very useful source of reference, it also appears to contain some identification errors. Brown focussed on weeds of agricultural land, and therefore her report describes only a subset of the total flora. At the turn of this century, Philip and Myrtle Ashmole (Ashmole & Ashmole, 2000) compiled much of the existing literature in their informative book on the ecology of St. Helena and Ascension. Whilst another very significant step forward, their compendium is based largely on existing information and therefore repeats much of the earlier work, although is supplemented with new observations. A further update is much needed to provide an accurate, detailed and comprehensive record of the current picture.

For Ascension, the situation is even less well advanced. The first botanical account in 1664 described just four species for the island (see Ashmole & Ashmole, 2000), and additions were made only very slowly, with the first reports from Green Mountain (the home of most of the endemic plants) awaiting the visit of J.D. Hooker in 1854, during which time the garrison had already established extensive agriculture and farming, and shortly before Hooker's plans to "green" the island lead to the massive influx of non-native species we see today. Whilst the programme of introductions was at least partially documented, the archive papers have never been fully researched and much remains unknown regarding the timing and nature of the arrivals. The only detailed floristic assessment was made by Eric Duffey in the 1950s (Duffey, 1964), and although apparently recording quite comprehensive information, not all of it was published. Between the 1970s and 1990s, John Packer added gradually to the assembled knowledge (Packer, 2002), and Wendy Fairhurst (2004) eventually developed this into a field guide. Despite both authors working with limited identification facilities on an extremely challenging and varied range of introductions, their privately-published works constitute an invaluable record.

From these existing sources, we can gain many useful clues regarding changes to the flora and habitat composition of both islands, but in neither case do we have more than a very sparse knowledge of the spread of introduced species. Little precise information on the historical distribution of the non-native species is available in order to estimate their spread or decline.

Botanical survey 2008: Methodology

Timing, personnel and knowledge base

Floristic surveys were conducted in 2008 by a small team of fieldworkers, and additional untrained volunteers. Fieldwork on St. Helena took place between January and early June, although extremely high levels of rainfall were experienced between March and May, which hampered efforts to finish the task and meant that two grid squares were not completed (at Deep Valley and Frightus Rock). Both involved dangerous cliff descents which were advisedly only undertaken in good conditions, although it is still hoped to return to them at a later date. The Ascension survey followed after this, between August and December. Due to the smaller size and less complex flora and topography of this island, it was possible to achieve a more comprehensive coverage, and in this case the previously heavy autumn rains across the South Atlantic worked in our favour, because winter germination in the lowland areas appeared to be unusually high, according to local accounts.

Most surveying trips were undertaken by two people, although sometimes only one and occasionally up to five. None of the survey team had an extensive knowledge of the flora at the beginning of the work, but the botanist dedicated to the survey (Phil Lambdon) spent 2 months at the Royal Botanic Gardens, Kew (London) researching and examining herbarium specimens as part of his preparation. South Atlantic Invasive Species Officer Andrew Darlow, who had several years experience in conservation issues on St. Helena, became rapidly familiarized with the species at the start of the survey and undertook a large part of the St. Helenan work and the early stages of the Ascension leg. Weed control specialist Tom Belton assumed the second main surveyor role during the later stages. Keen local volunteers were also recruited to participate in many trips (see Acknowedgements), accruing botanical knowledge over the course of the project. However, due to limitations imposed by topography, recording consistency and experience, the survey team generally operated together, the main benefit of the additional recorders being to increase vigilance rather than to cover additional ground.

Many unfamiliar exotic species were encountered as the survey progressed, and efforts were made to establish preliminary identifications for these as soon as possible. A limited number of floristic literature sources were available on the islands, and extensive internet searches were used to access on-line keys and image resources. In nearly all cases, the specimens were assigned to a provisional family and genus within a few days. Voucher herbarium specimens and digital photographs were collected in order to verify any uncertain species, and the final identification was attempted at the end of the survey by comparison with reference material held at Kew Gardens. These specimens are now lodged in Kew Herbarium, with some replicates at the Royal Botanic Gardens in Edinburgh.

In order to gain a broad understanding of the ecology of plant species it is useful to record data at different spatial scales. We focussed on two forms of recording methodology to provide a picture of both large-scale distributions, and also to improve knowledge of smaller scale interactions at the community level. The two forms of recording methodology are described in the following sections.

Large-scale distribution mapping

We attempted to map the distribution of all higher plants and ferns (Trachyophyta) occurring in wild situations on each island, based on their presence or absence in each cell of the Ordinance survey 1km grid. This approach gives a coarse but useful estimate of distribution, achievable in a relatively short time frame, and is widely used around the world as a standard approach to mapping. It is compatible with the recent assessment of the U.K. flora (Preston *et al.*, 2002). However, this methodology is subject to some criticisms that the level of detail it supplies can be misleading when the patterns are subject to more detailed analysis. For example, the presence of one stray plant, perhaps confined to a very rare habitat type, is recorded as a “presence” within a grid cell, thus granted equivalent weight to any common, widespread species. Such coarse resolution may obscure subtle yet important trends. To improve the usefulness of the approach, we have experimented with three innovations to the basic methodology:-
1) We have scaled the size of the mapped symbols to reflect the abundance of the species.
2) On Ascension, we used finer-resolution grid cells (0.5 km × 0.5 km) to cover Green Mountain, where the vegetation is denser and more complex.
3) We incorporated this mapping approach with the complimentary community-level assessments described in the next section, in order to address more complex ecological questions more directly.

It is clearly not possible for a few people to survey every single plant in a 1km grid cell and our maps therefore stand as provisional, awaiting improvement by subsequent botanical recorders. We aimed to spend at least 3-5 hours in each cell, usually managing to walk several routes and covering most of the territory at least briefly. Some cells required more effort than others, either due to difficult terrain or due to the complexity of the vegetation, and we attempted to invest effort accordingly, in each case recording the length of time spent. Because the survey was spread over several months, it is inevitable that some species would have been missed on each occasion because the season was unsuitable (especially during the dry part of the summer). To minimize any biases caused by these omissions, we spread visits to each part of the island across the entire survey period, and therefore will have made excursions to different routes in the same cell, or at least to adjacent cells, in differing seasons. Unfortunately, some winter germinating species on St. Helena may have been missed completely as this part of the year fell outside the survey period, but from local knowledge and the occasional occurrence of dead stems, we were able to piece together an approximate distribution of a few such species (e.g. *Homeria colina*).

If the survey was to be repeated at a later date to assess changes in distribution, the comparison would only be valid if our efforts were replicated faithfully. As we aimed to achieve the most comprehensive coverage practical, this would be almost impossible, perhaps due partly to the extensive time investment but mainly due to the impracticalities of retracing every small-scale searching movement in detail. To make such comparisons easier, we designated one route as a transect across the cell. The transect followed a well-defined path, a diagonal or a linear traverse across the cell and aimed to encompass a representative sample of the habitats present. All transects were tracked by GPS and their routes recorded in a specified layer within the GIS. It is intended that a snap-shot of change could be assessed by re-walking the transect network in the future, both quickly and with a high degree of consistency.

All plant species observed in the cell were listed and the following information recorded for each:-
1) wild abundance across the entire cell, on a DAFOR scale (see Appendix 1A).
2) wild abundance within 20 metres on either side of the walked transect (or as far as visibility would allow if this distance was not possible), also according to the DAFOR scale.
3) a score to assess the frequency with which the species was cultivated within the cell, according to a 3-point scale (see Appendix 1C).
4) A record of the habitats in which they occurred, and the estimated proportion of the population in each. A list of 83 habitat categories (see Appendix 1D) was drawn-up specifically to reflect the predominant broad habitat types on the islands, using previous literature descriptions to develop an appropriate system (e.g. Cronk, 1989). Each was designated to represent a sub-category of one of the coarser IUCN habitat types (I.U.C.N., 2008), to ensure that the data could be usefully compared with other parts of the world.

Much of the descriptive data were best recorded in "overview", after the cell had been completed. In addition, a difficulty score (according to a 5 point scale) was allocated to each cell and transect respectively, as a future guide to the practicalities of tackling a repeat survey. On Ascension, a list of the habitats available in the entire cell was also made, and the proportions of the total area occupied recorded as above (whilst this information would also have been very useful for St. Helena, it was not possible to collate it in the time available). At the end of the survey, each of the recorded species was assigned a status to indicate their native origin and their current level of establishment (see Appendix 1E).

Community level assessment

Numerous assessment points were selected across the islands for more detailed community level data recording. At least 2 points were chosen at random within each of the surveyed grid cells, selected at the discretion of the surveyor but intended to represent habitats typical of the cell, or occasionally, rarer habitats that were characteristic of the local area. Examples of such habitat include river valleys, coastal slopes and native vegetation relicts, which are often ecologically important but cover a small proportion of the land surface so are inadequately sampled by random selection. To increase the sample size available for analysis of such habitat composition, we therefore supplemented the random data set with a number of "community points", which were chosen at random *within* such key habitats. The same data was collated for random and community points, but the latter offered a spatially biased rather than a random sample of the islands' general ecology, and have therefore been excluded from analyses intended to show a general snapshot of the vegetation. A third type of assessment point, the "species point", was also sometimes employed to describe the habitat of a particular rare species of interest. Again, these data are spatially biased because rare species tend to be restricted to a few localized areas, but the information is useful to compare their ecological requirements with the general availability of the habitat. Species points were always recorded when a herbarium specimen was collected.

At each assessment point, an inferred circular zone was designated as the study quadrat. For random points, the quadrat was always 20 metres in radius, which proved to be a suitable size given the very sparse vegetation cover over much of the island. For community and species points, the radius was chosen to be appropriate to the size of the relevant habitat type, although was maintained at 20 metres where possible. The location was photographed as a visual phenological record. Simple physical characteristics of the quadrat were assessed to describe the terrain (see Appendix 1F), and the % cover of different habitat types was noted using the categories listed defined above (see Appendix 1D) with the addition of further categories for "bare ground" and "moss swards". A species list was then compiled, and for each species a DAFOR abundance score was estimated. Due to the very different scale on which abundance was being assessed compared with the grid cell evaluations, the score criteria were necessarily different, and based on % covers (see Appendix 1B).

For each island, we decided on a list of approximately 20 target species, including many of the most common invaders but representing a wide range of ecological types and habitats. For these (and also for the focal species of "species points"), we recorded additional population data within the quadrat in order to assess some key characteristics of their success (see Appendix 1G).

Data recording

All data were logged directly onto computerized systems, mostly in the field. The survey team carried a LOOX Personal Data Assistant, with a built-in GPS and capable of running ArcPad (ESRI inc.): a portable GIS recording system with limited functionality. Essential base layers (e.g. digital maps, elevation contours, satellite images) were supplied by the islands' custom-designed GIS management units: SHEIS on St. Helena and AEIOU on Ascension. The GIS data was used to track the surveyors' position and to log spatial locations where required.

In order to record the necessary ecological information, a relational database was designed, capable of storing a range of complex fields linked by many-to-one relationships, and forms were created to permit easy data entry. On St. Helena, we used Visual CE (Syware inc.), a portable databasing system loaded onto the PDA, for data recording, with the system synchronized onto an MS Access database each evening. This made the data available in a manipulatable form on a laptop computer. Unfortunately, by the end of the survey, the Visual CE system was almost overwhelmed by the volume of data and subject to synchronization problems. On Ascension, a UMPC was purchased, which could run MS Access directly in the field, although this was again subject to some problems as the battery life was more limited. In both systems, the ecological data was linked to a spatial reference via a spatial identifier field.

Further analysis was undertaken later, using both queries to process the raw ecological data in MS Access, and ArcMap (ESRI inc.) to manipulate and present the spatial information. Thus far, the community level assessment data has not been analysed in detail, and the summary therefore focuses on the findings revealed from the large-scale mapping.

The state of the modern flora

St. Helena

A total of **431** higher plant species were recorded growing in wild situations. They break down into the status categories shown in Table 1.

Table 1. Status categories of the modern flora of St. Helena

Status	Number of species
Endemic	43
Possibly endemic	1
Other native	12
Probably native	5
Possibly native	5
Naturalized	258
Forestry species	19
Adventive	68
Cultivated in wild situations	20

Native species

Eight endemic species and one subspecies are now thought to be extinct. Seven of these were lost in the historical past (Table 2). As a result of the recent survey work, two further species can be provisionally added to this list of likely extinctions (Table 3).

Table 2. St. Helena endemic plant species previously recorded as likely to be extinct, and their approximate last recorded dates.

Species	Common name	Approximate date of last record
Trochetiopsis melanoxyon	Dwarf ebony	1771
Heliotropium pannifolium	Burchell's heliotrope	1825
Acalypha rubrinervis	Stringwood	1855
Wahlenbergia roxburghii	Roxburgh's bellflower	1872
Wahlenbergia burchellii	Burchell's bellflower	1877
Commidendrum robustum ssp. gummiferum	Cluster-leaved gumwood	2000
Nesotia elliptica	Wild olive	2000

Table 3. St. Helena endemic plant species which may have become extinct recently, according to the current survey.

Species	Common name	Approximate date of last record
Lycopodium axillare	St. Helena buck's-horn	2005
Dryopteris cognata	Large kidney fern	2000

Of the two, *L. axillare* is very likely extinct, although there remains some hope of finding *D. cognata* amongst the dense vegetation of the Peaks, and efforts to relocate it should therefore be an immediate priority. To offset these latest losses, one species previously thought to be extinct was rediscovered. The tiny annual *Bulbostylis neglecta*, the neglected tuft sedge, was located on three ridges around the High Hill area, having been previously recorded only by W.J. Burchell on 1806, and later by an un-named collector in the 1870s. It is apparently still thriving, although persists mostly on loose, eroded slopes with little other vegetation, and all habitat areas are under very immediate threat from encroachment by invasive vegetation. In addition, one further species, a grass of the genus *Eragrostis* which occurs on cliffs along the south side of the island, has yet to be identified, and could turn-out to be a previously unrecognised endemic or native variety.

The two latest extinctions add to the spate of recent tragedies. Although the numbers of species involved are small, St. Helena's endemic species are currently being lost at an unprecedented rate – an alarming fact given that the infrastructure to preserve biodiversity is now stronger than it has ever been. The worrying trend is clearly not entirely due to recent negligence on the part of the conservation bodies, but is a legacy of the gradual decline in habitat quality which has resulted in a slow dwindling of populations until they are no longer sustainable. The consequences are only now being realized, some time after the main damage was inflicted. However, it does underline the fact that only intensive, immediate effort can save species facing a similar fate. Our survey clearly shows that a number of endemic species have much smaller populations than previously thought, several of which are possibly no longer sustainable without intervention. The following list of species may fall into this category, either because the populations are too dispersed to pollinate and recruit new seedlings successfully or because they are extremely small and vulnerable to chance catastrophes.

Chenopodium helenense	St. Helena goosefoot
Euphorbis heleniana	French grass, St. Helena spurge
Pelargonium cotyledonis	Old father live forever
Trochetiopsis erythroxylon	Redwood[1,2]
Trochetiopsis ebenus	St. Helena ebony[2,3]
Frankenia portulacifolia	Teaplant
Phylica polifolia	St. Helena rosemary
Sium burchellii	Dwarf jellico
Mellissia begonifiolia	Boxwood
Wahlenbergia linifolia	Large bellflower
Commidendrum rotundifolium	Bastard gumwood[1]
Lachanodes arborea	She-cabbage tree[2]
Hymenophyllum capillaceum	St. Helena filmy-fern
Dryopteris napoleonis	Small kidney fern
Asplenium platybasis	Sickle-leaved spleenwort
Ceterach haughtonii	Barn fern
Elaphoglossum dimorphum	Toothed tongue-fern
Elaphoglossum nervosum	Veined tongue-fern
Grammitis ebenina	Strap fern

[1]Extinct in the wild.
[2]Advanced efforts are under way to reintroduce material from cultivation.
[3]Although shrubs have been widely planted in the wild for reintroduction purposes, the low seed viability currently prevents the populations from being self-sustaining.

A smaller number of other native species are also in danger of extinction on St. Helena. Although these species are not necessarily threatened at a global level, they remain an important part of the island's natural heritage and represent relicts of the original vegetation of the island. The extinction of any would therefore be a serious loss, which in certain cases may be prevented by simple conservation measures if sufficient foresight is given the problem.

Cheilanthes multifida	
Elaphoglossum conforme	Common tongue-fern
Commicarpus helenae	Hogweed
Ipomoea pes-caprae	Camel's-foot creeper[1]
Tribulus cistoides	

[1]The native population may already be extinct. Now only known from one location, and may have been introduced here although there is no clear evidence of provenance.

Whilst these lists offer only a provisional and subjective opinion on the present threat status, it underlines the need for a re-evaluation of St. Helena's native and endemic species according to more scientific criteria. A revision of the IUCN red list would be a useful starting point to achieve this, and this would require the collection of new data which should help to establish what further action is needed.

Introduced species

One clear contributor to the decline in the native flora is the introduction and spread of a great many introduced plants. Even under the assumption that all of the potentially natives do indeed fall in this category, the total number is a mere **66** species. This is only **15%** of the overall total, when all **365** introductions are included. Although indicative of a drastic change, this statistic still under-represents the dominance of the introduced flora in terms of territory occupied. One simple measure of this is the number of km grid cells in which the species were recorded. When ranked by this criterion, introductions occupy the great majority of the top positions (Fig 1). The most common native species are *Portulaca oleracea* (purslane) and *Suaeda fruticosa* (samphire), in **15th** and **31st** places respectively, and the most abundant endemic is *Bulbostylis lichtensteiniana* (tussock sedge) in **76th** position.

There is no clear distinction between "native" and "alien" habitats, because in most cases the two groups of species occur intermixed. However, most habitats are heavily dominated by introductions and can be clearly defined as alien. Only the remaining fragments of tree fern thicket and cabbage tree woodland in Diana's Peak National Park and at High Peak are heavily dominated by natives. Even including miscellaneous areas such as the gumwood stand at Peak Dale and the scrubwood scrub at Blue Point (both occupied by a dominant native species but heavily invaded by a non-native understorey), the total area occupied by native habitats cannot be much more than **1%** of the island. Parts of the south coast are almost barren of vegetation except for a very sparse scattering of the endemic *Hydrodea cryptantha* (babies' toes), but these can hardly be considered as unambiguously native habitat.

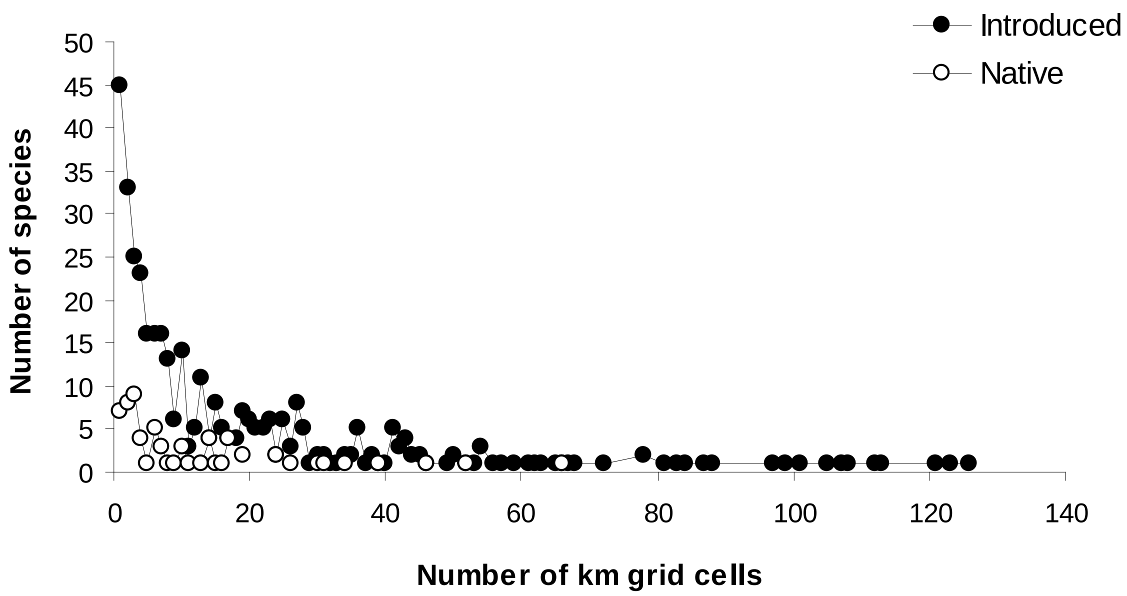

Figure 1. Abundance distribution curves for both native and introduced species on St. Helena. In this case, abundance is measured as the number of grid cells in which the species was found during the survey.

The 12 most abundant species on St. Helena, based on grid cells occupied, are shown in Table 4.

Table 4. The "Top 12" invasive species on St. Helena, when ranked according to the number of grid cells occupied.

Family	Species	Common name	No. of km grid cells
Verbenaceae	*Lantana camara*	Lantana	126
Asteraceae	*Conyza bonariensis*	Fleabane	123
Anacardiaceae	*Schinus terebinthifolius*	Wild mango	121
Asteraceae	*Chrysanthemoides monilifera*	Wild coffee	113
Asteraceae	*Ageratum conyzoides*	Blueweed	112
Asteraceae	*Sonchus oleraceus*	Smooth sow-thistle	108
Poaceae	*Sporobolus africanus*	Cape grass	107
Cactaceae	*Opuntia stricta var. dillenii*	Red tungy	105
Chenopodiaceae	*Atriplex semibaccata*	Saltbush	101
Oleaceae	*Olea europaea ssp. africana*	Wild olive	99
Cupressaceae	*Juniperus bermudiana*	Bermudan cedar	97
Aizoaceae	*Carpobrotus edulis*	Creeper	88

A list based on such simple criteria does not accurately reflect the degree of threat posed by the invaders. Threat depends on the ecology of the species, the type of habitat invaded, and whether the colonizer conflicts with any local interests. As a simple illustration of this, certain species may be very widespread but only occur rather thinly in any one place. *Conyza bonariensis* (fleabane) is a good example of a plant which has spread very rapidly across a very wide range of habitats, from barren coastal semi-desert to roadside banks along the Peaks Ridge, but it is short-lived, rarely forms dense stands and is usually present at low densities, only becoming potentially problematic as a sporadic arable weed in cultivated areas.

To give a more accurate reflection of true abundance an abundance index was created from the sum of the DAFOR scores (see Appendix 1A) assigned to the species in each of the grid cells in which it occurred. Since the DAFOR scale is intended to be approximately logarithmic (e.g., a Frequent species may be 10 times more abundant than an Occasional species and 100 times more abundant than a Rare species), this is reflected by allocating a numerical value to each category on a $\log_{10}$ scale: Very rare = 1, Rare = 10, …, Dominant = 1 000 000. When ranked by this method, the 12 most dominant species are shown in Table 5.

Table 5. The "Top 12" invasive species on St. Helena, when ranked according to their summed abundance scores.

Family	Species	Common name	Abundance score[1]
Anacardiaceae	*Schinus terebinthifolius*	Wild mango	149.7
Verbenaceae	*Lantana camara*	Lantana	145.6
Asteraceae	*Ageratum conyzoides*	Blueweed	131.6
Cactaceae	*Opuntia stricta var. dillenii*	Red tungy	128.7
Chenopodiaceae	*Atriplex semibaccata*	Saltbush	125.0
Poaceae	*Sporobolus africanus*	Cape grass	118.5
Asteraceae	*Conyza bonariensis*	Fleabane	114.6
Aizoaceae	*Carpobrotus edulis*	Creeper	110.9
Asteraceae	*Chrysanthemoides monilifera*	Wild coffee	109.5
Cupressaceae	*Juniperus bermudiana*	Bermudan cedar	103.8
Poaceae	*Pennisetum clandestinum*	Kikuyu grass	94.3
Asteraceae	*Sonchus oleraceus*	Smooth sow-thistle	91.5

[1]The abundance score is the sum of the individual DAFOR values for each grid cell, averaged by the number of cells on the island.

This measure certainly gives a more accurate reflection of threat and is produces a useful reference list, although it still omits a number of more locally problematic invaders and includes some less damaging species (e.g. *Atriplex semibaccata*, which has been present for a long period, is reasonably well integrated with the ecology of the island and serves a useful role in preventing erosion). In general, it can be stated that species with a "dominant ecology", i.e., those which come to form the dominant component of the ecosystems they thrive in, are the most problematic because they are most likely to form dense populations, are often aggressive and difficult to remove, compete with natives and substantially affect the way in which the ecosystem functions. The "top-ranked" species, *Schinus terebinthifolius* (wild mango), clearly falls into this category, as do *Lantana camara*, *Opuntia strica* var. *dillenii*, *Carpobrotus edulis*, *Chrysanthemoides monilifera* and *Juniperus bermudiana*. However, to some extent, their widespread occurrence also reflects a tolerance of broad habitat requirements. A number of other species with equally dominant ecologies occur lower down the rankings because they are confined to particular climatic zones, even though they form the same types of monoculture where they occur. Further discussion of the problems caused by such species is presented in the next section.

Changes in the flora over historical time

To put the current situation in context, it is useful to gauge how the alien colonization has progressed over time. Is the rate of still invasion increasing, or has the island settled into a new *status quo*? Although such a question is extremely important to inform current management strategies, it is a difficult one to answer due to the lack of detailed accounts which can be used to reconstruct the history of plant introductions on the island. The work of J.C. Melliss in the mid 19th Century (Melliss, 1875) provides the most complete record of past floras, and thanks to detailed notes, it is possible to make a reasonable guess at the status (naturalized, forestry of adventive) of the alien species at this time. Table 6 compares Melliss's total's with those of the present day.

Table 6. A comparison of the numbers of introduced species and their statuses recorded by Mellis in 1864 with those of the current survey.

Status	No. of species (1864)	No. of species (2008)
Naturalized	176	258
Forestry species	9	19
Naturalized/Adventive (ambiguous)	18	0
Adventive	83	68
TOTAL	**286**	**345**

These statistics suggest a **21%** increase in the number of aliens present over the past 150 years. This trend is marked by a tendency for more species to become fully naturalized, the number having risen by **48%**, whereas that of adventive species has fallen. However, this underlies a more complex pattern of extinctions and colonizations. Of the species which were naturalized in Melliss's day, **30%** are no longer found on the island, and only **22%** of the adventive species are still present. Of those species which were not fully established, only a small fraction ultimately succeeded, and even some which were apparently quite abundant according to the historical records have now disappeared, including mainly ruderal and urban weeds such as *Achyranthes aspera*, *Withania somnifera* and *Adonis annua*. Changing environmental conditions are likely to be partly responsible for the failures, which may be climatic but probably mainly a result of the dramatic shifts in land management, with the advent in the flax industry, declines in agriculture and new fashions in forestry practices. Some widely-cultivated species, apparently also well-established in the wild (e.g. oat *Avena sativa* and Scot's pine *Pinus sylvestris*), disappeared after the market for their consumption dwindles and they ceased to be grown. Other species may have been lost due to more random chance events.

Unfortunately there is insufficient information available to adequately assess more recent trends in species numbers. 150 years is a relatively long time period, and many new species, especially ornamental garden plants brought in with changing fashions, have been introduced since this time. Greater mechanisation leading to larger-scale forestry, the effect of the flax industry which dominated the island for much of the 20th Century, the subsequent decline in the economy as the flax market collapsed, and a rise in environmental awareness leading to focused conservation efforts and better biosecurity policies, will all have had a marked influence on invasion dynamics. The works of R.O. Williams (Williams, 1970) and R.L. Brown (1981) give a useful impression of recent trends and merit a more detailed analysis in the future. At a qualitative level, Brown's work indicates a marked decline in agricultural weeds, with a number of species (e.g. corn spurrey *Spergula arvensis*, sticky mouse-ear *Cerastium*

Table 7. Species newly-recorded for St. Helena in the current survey.

Family	Species	Common name
Aizoaceae	*Malephora purpureo-crocea*	
Aizoaceae	*Trianthema portulacastrum*	Horse purslane
Aloaceae	*Aloe arborescens*	Tree aloe
Amaranthaceae	*Amaranthus blitoides*	Prostrate amaranth
Amaranthaceae	*Amaranthus dubius*[1]	
Amaranthaceae	*Amaranthus muricatus*	African amaranth
Araceae - Aroideae	*Pistia stratiotes*	Water lettuce
Asparagaceae	*Asparagus plumosus*	Asparagus fern
Asparagaceae	*Asparagus densiflorus*	Climbing asparagus
Asteraceae	*Schkuhria pinnata*	Ragweed
Asteraceae	*Soliva sessilis*	Lawnweed
Begoniaceae	*Begonia sp.*	
Bignoniaceae	*Campsis grandiflora*	Trumpet vine
Caprifoliaceae	*Lonicera japonica*[1]	Japanese honeysuckle
Caryophyllaceae	*Cerastium fontanum*[1]	Common mouse-ear
Crassulaceae	*Kalanchoe daigremontianum*	Mother-of-thousands
Euphorbiaceae	*Euphorbia cyathophora*	Mexican fireplant
Fabaceae-Faboideae	*Lablab purpureus*	Hyacinth bean
Fabaceae-Mimosoideae	*Acacia karroo*	Sweet thorn
Iridaceae	*Chasmanthe floribunda var. floribunda*	African flag, cobra lily
Lamiaceae	*Plectranthus barbatus*	Indian coleus
Lamiaceae	*Plectranthus verticillatus*	
Malvaceae	*Urena lobata*[1]	Caesarweed
Poaceae	*Dichanthium aristatum*	
Poaceae	*Digitaria violascens*[1]	
Poaceae	*Lolium rigidum*	Annual rye-grass
Poaceae	*Oplismenus hirtellus*	
Poaceae	*Pennisetum setaceum*	African fountain grass
Poaceae	*Poa trivialis*	Rough meadow-grass
Poaceae	*Semiarundinara sp.*[1]	
Poaceae	*Stipa neesiana*	
Polygonaceae	*Polygonum capitatum*	
Portulacaceae	*Portularia afra*	Speckboom
Portulacaceae	*Talinum paniculatum*	Jewels of Opar
Scrophulariaceae	*Veronica officinalis*	Heath speedwell
Solanaceae	*Solanum pseudocapsicum*	Jerusalem cherry
Tetragoniaceae	*Tetragonia microptera*	
Tiliaceae	*Triumfetta rhomboidea*	Chinese burr

[1]May have been recorded previously under an erroneous name

glomeratum and red pimpernel *Anagallis arvensis* subsp. *arvensis*) apparently disappearing over the past 25 years. These extinctions are consistent with the substantial loss of agriculture to pasture and forestry over this period, mainly due to the ready availability of cheap food imports from South Africa. Increased use of herbicides, which has been widely attributed as the cause of recent arable weed declines over much of the developed world, has probably played a minor role on St. Helena where they are still relatively difficult to obtain and comparatively little used.

Set against this, at least **38** species new to the island were recorded in the recent survey (Table 7). Assuming that these aliens have all appeared within the past 40 years, the rate of arrival is a little below 1 species per year, which suggests that the problem remains as great as it has been throughout much of the historical period. Many of the introductions are adventive species and it remains to be seen whether they eventually become established, although a number are already present in reasonable numbers. *Acacia karroo* is threatening to become a serious weed in upper James Valley, and *Tetragonia microptera* is a community dominant along much of the very barren north coastal fringe. *Pennisetum setaceum* is spreading extremely rapidly across the west of the island where it is already a major invasive. Despite the very high visual impact of this species, its presence, and potential threat, had apparently not been noted. That even one species can reach this level of ecological concern underlines the need for improved biosecurity and early warning measures.

Introductions have had a marked overall effect of on the composition of the St. Helena flora (Table 8). During the pre-human period, the landscape was dominated by relatively few families (approximately **34** according to current knowledge), especially trees of the Asteraceae, and with an understorey comprising many types of fern across much of the uplands. The recent arrivals comprise at least **113** different families, heavily skewed towards the Dicotyledonae (with many more types of herb), and the number of grasses has also risen substantially, from **2-3** species to **66**. Gymnosperms, originally absent from the native flora, are now represented by large areas of pine and *Podocarpus* forest. In practice, much of this new flora inhabits man-made landscapes, including ruderal, agricultural, forestry and pastureland. The high altitude native habitats (cabbage tree woodland and tree fern thicket) has proved to be relatively difficult to invade and remains relatively pristine, but the drier, lowland semi-natural areas have been more seriously affected. Where native species persist, they must now survive in heavily modified environments with new competitors and ecosystems which function in different ways.

Table 8. The higher taxonomic composition of the native St. Helena flora compared with that of the introduced flora at the time of Mellis (1864) and according to the current survey (2008).

(Sub-)class	Natives	Introductions (1864)	Introductions (2008)
Pteridophyta	30.6%	0.6%	1.5%
Gymnospermae	0%	2%	1.1%
Dicotyledonae	53.3%	70.7%	63.5%
Monocotyledonae	16%	26.4%	33.7%

Ascension Island

Given the more barren terrain of this much younger island, substantially fewer higher plant species occur on Ascension compared with St. Helena, with **248** recorded from wild situations. They break down into the status categories shown in Table 9.

Table 9. Status categories of the modern flora of Ascension Island

Status	Number of species
Endemic	6
Other native[1]	12
Probably native	5
Possibly native	2
Naturalized	173
Adventive	37
Wild planted[2]	21

[1]Includes one fern of the genus *Ophioglossum*, which has yet to be identified correctly and could possibly be a cryptic endemic microspecies.
[2]There is no active forestry on Ascension, but this total mainly includes tree species planted in small stands around Green Mountain.

Native species

Before the arrival of humans, Ascension was an extremely barren place, the lowlands intruded by fresh, young lava flows and sparsely colonized by the few pioneering natural arrivals. Numerous travellers, including Charles Darwin on the return voyage of the Beagle reported with horror on the hostility of the environment, the German P. Osbeck typically claiming in 1752 that "*I never saw a more disagreeable place in all the world than this island*" (see Ashmole & Ashmole, 2000). Remarkably, no more than **29** possible natives have ever been recorded. This may be a slight underestimate of the total due to the paucity of early accounts. It is possible that a few endemic species may disappeared without ever being described, and of the persisting species, it is now difficult to assess which were present before the interference of man. The 6 surviving endemic species cling to survival at a few restricted sites, and 4 further species are believed to be extinct (Table 10).

Table 10. Ascension Island endemic plant species likely to be extinct, and their approximate last recorded dates.

Family	Species	Approximate date of last record
Adiantaceae	*Anogramma ascensionis*	1954
Dryopteridaceae	*Dryopteris ascensionis*	1851
Rubiaceae	*Oldenlandia adscensionis*	1888
Poaceae	*Sporobolus durus*	1888

Even by the 1880s, the forays which had lead to the final collections of three of these species remained, in botanical terms, pioneering explorations of the less accessible interior. *Sporobolus durus* is only known from a single specimen and *Dryopteris* *ascensionis* is barely better known. Only *Anogramma ascensionis*, last recorded by Eric Duffey, stands more than a vanishingly small chance of persisting, perhaps in rock crevices on the steep, inaccessible gulleys of Green Mountain.

The surviving natives all have a very restricted distribution:

Pteris adscensionis	
Marattia purparascens	
Asplenium ascensionis	Ascension Island spleenwort
Xiphopteris ascensionense	
Euphorbia origanoides	Ascension Island spurge
Sporobolus caespitosus	

Several of these have closely-related sister taxa on mainland Africa, and are dubiously classed as distinct species, although all have clearly diverged substantially in isolation from other populations and it is important to conserve such unique lineages as part of the island's ecological heritage. Only the spleenwort is still thriving, although local, in rocky places on the mountain. The remainder have extremely small and/or restricted populations. Both *Sporobolus caespitosus* and the *Pteris adscensionis* have dwindled to a few rock outcrops, and in the case of *Marattia purpurascens*, the last major stand is threatened by the encroachment of vigorous invasive species. The Ascension Island spurge, which forms ephemeral populations on unstable coastal desert, is vulnerable to rabbit grazing and has declined substantially over the past 60 years (c.f. Gray *et al.*, 1998).

The handful of other natives are an interestingly diverse assortment of mainly dryland species, and are generally not threatened. Indeed, when species are ranked according to the number of squares in which they are present, three native species occur in the top 10 list. Only the grass *Polypogon tenius* is local, being restricted to black cinder banks on the weather side of Green Mountain.

Introduced species

Many remote oceanic islands are now characterized by impoverished and threatened native floras being heavily invaded by an assortment of introduced species, but Ascension Island represents an extreme case of the typical pattern. The low native diversity, coupled with a prolonged and deliberate programme of introductions designed to vegetate the island, initiated by J.D. Hooker in the mid 19th Century (Hart-Davis, 1972), have resulted in a landscape overwhelmingly dominated by aliens. In addition, the effects of introduced grazing mammals (goats, donkeys, sheep and rabbits) probably had a similarly impact on the early flora to that better documented on St. Helena. The resulting composition shows **93.2%** of species in wild situations to be non-native. Virtually nothing remains which could be categorized as a truly "native" habitat, although native species may be fairly well represented across the very barren dryland areas, even if at low densities. When ranked according to the number of km grid cells occupied (Table 11), several natives perform well, with purslane *Portulaca oleracea* and the grass *Aristida adscensionis* **2nd** and **3rd** on the list respectively. However, the most abundant endemic is Ascension Island spurge *Euphorbia origanoides*, which is ranked as low as **76th**. The remainder of the top-ranked species are common invasive species around many parts of the tropics.

Table 11. The "Top 15" invasive species on Ascension Island, when ranked according to the number of grid cells occupied.

Family	Species	Common name	Status	No. of grid cells
Asteraceae	*Ageratum conyzoides*	Blueweed	Naturalized	120
Portulacaceae	*Portulaca oleracea*	Purslane	Native	100
Poaceae	*Aristida adscensionis*	Triple-awn grass	Native	96
Papaveraceae	*Argemone mexicana*	Mexican poppy, thistle	Naturalized	94
Verbenaceae	*Lantana camara*	Lantana	Naturalized	93
Fabaceae-Mimosoideae	*Prosopis juliflora*	Mexican thorn	Naturalized	90
Poaceae	*Enneapogon cenchroides*		Possibly native	86
Solanaceae	*Solanum nigrum*	Diddly dight	Naturalized	81
Sterculiaceae	*Waltheria indica*	Velvetleaf	Naturalized	79
Boraginaceae	*Heliotropium curassavicum*	Tropical heliotrope	Naturalized	77
Euphorbiaceae	*Euphorbia hirta*	Pill spurge	Naturalized	72
Cactaceae	*Opuntia stricta* var. *dillenii*	Red tungy	Naturalized	70
Solanaceae	*Nicotiana glauca*	Tree tobacco	Naturalized	69
Myrtaceae	*Psidium guajava*	Guava	Naturalized	68
Bignoniaceae	*Tecoma stans*	Yellowboy	Naturalized	66

The use of the number of grid cells is valuable for assessing range size, but on Ascension it is less successful at identifying the aggressive dominant species which generally cause the greatest management problems. A large part of the island is covered by sparsely-vegetated lowland desert, and at present, few of the alien colonists of this habitat occur at high enough densities to create ecological issues. In fact, many species are so thinly-dispersed that there may be only a few plants in each grid cell. The use of the abundance index described for St. Helena (see Table 5 for methodology) provides a more realistic view of the major ecological threats (Table 12), although still contains a moderately high representation of introduced dryland herbs, which are often common but rarely dominate ecosystems and are therefore not perceived as a major issue.

Never the less, the revised list highlights a range of considerations. The three most serious invasive species across the lowlands are Mexican thorn *Prosopis juliflora*, guava *Psidium guajava* and yellowboy *Tecoma stans*, all of which have a tall, shrubby growth form and are capable of dominating areas, creating virtual monocultures which support little biodiversity. They occupy different parts of the island, with Mexican thorn prevalent across the western basin, guava along the more humid, wind-exposed southern and eastern plateaus and yellowboy around the foothills of Green Mountain. Despite the obvious impact of this trio, the effects of other colonists should not be ignored. The two highest ranked species, the grass *Enneapogon ce*nchroides and blueweed *Ageratum conyzoides*, are annuals, well adapted to the dry wastes. Both have spread to become rather sparse but dominant over some areas, and clearly have an effect on the ecology of the previously barren habitats. Tropical heliotrope *Heliotropium curussavicum* is becoming similarly dominant along the coastal fringe, and whilst other herbs such as Mexican poppy *Argemone mexicana* (known locally as thistle) and pill spurge *Euphorbia hirta* are more local, the combined effect is to create an increasingly more vegetated environment.

Table 12. The "Top 15" invasive species on Ascension Island, when ranked according to their summed abundance scores.

Family	Species	Common name	Status	Abundance score[1]
Poaceae	*Enneapogon cenchroides*		Possibly native	105.28
Asteraceae	*Ageratum conyzoides*	Blueweed	Naturalized	97.1
Fabaceae-Mimosoideae	*Prosopis juliflora*	Mexican thorn	Naturalized	89.7
Poaceae	*Aristida adscensionis*	Triple-awn grass	Native	84.4
Verbenaceae	*Lantana camara*	Lantana	Naturalized	59.6
Boraginaceae	*Heliotropium curassavicum*	Tropical heliotrope	Naturalized	52.1
Solanaceae	*Nicotiana glauca*	Tree tobacco	Naturalized	51.1
Myrtaceae	*Psidium guajava*	Guava	Naturalized	48. 3
Papaveraceae	*Argemone mexicana*	Mexican poppy, thistle	Naturalized	47.8
Malvaceae	*Sida cordifolia*		Possibly native	45.4
Bignoniaceae	*Tecoma stans*	Yellowboy	Naturalized	40.2
Cactaceae	*Opuntia stricta* var. *dillenii*	Red tungy	Naturalized	40.0
Euphorbiaceae	*Euphorbia hirta*	Pill spurge	Naturalized	36.9
Poaceae	*Enteropogon mollis*		Naturalized	36.8
Molluginaceae	*Mollugo verticillata*		Naturalized	34.9

[1]The abundance score is the sum of the individual DAFOR values for each grid cell, averaged by the number of cells on the island. For cells over Green Mountain which were divided into 0.5 × 0.5 m subcells, the abundance score was multiplied by 0.25, a weighting designed to reflect the smaller area.

Still rather under-represented in the abundance rankings are those species which are localized to higher altitudes on Green Mountain. Although this area accounts for a relatively small proportion of the island, it is particularly important because it represents the most productive environment. Several of the native and endemic species are restricted to it, as is much of the land suitable for farming and recreation. Invasive species also grow rapidly here in lush, dense stands, thus accounting for a comparatively large proportion of Ascension's overall green biomass. Repeating the abundance rankings only for those squares which overly the Mountain and its foothills (i.e., those which were subdivided into 0.5 × 0.5 m subcells), reveals a different suite of dominant species (Table 13), this time comprised mostly of fast-growing, shrubby species, often capable of rapid clonal spread. Guava *Psidium guajava* is now the most abundant, underlining its wide ecological tolerance. Several new problematic invaders also emerge, including the sub-shrub *Spermacoce verticillata* (formerly known as *Borieria verticillata*), Bermudan cedar *Juniperus bermudiana*, greasy grass *Mellinis minutiflora* and Koster's curse *Clidemia hirta*.

Changes in the flora over historical time

The 1958 survey of Duffey (Duffey, 1964) provides a valuable, and probably the only, dataset which can be used to assess how the distribution of vegetation has changed over time. Unfortunately, although the methodology was similar to that of the recent survey, the grid was different, being based on the old, coarser system of 1 mile cells. One way

Table 13. The "Top 15" invasive species recorded from Green Mountain, when ranked according to their summed abundance scores.

Family	Species	Common name	Abundance score[1]
Myrtaceae	*Psidium guajava*	Guava	12.5
Asteraceae	*Ageratum conyzoides*	Blueweed	12.1
Rubiaceae	*Spermacoce verticillata*		9.5
Verbenaceae	*Lantana camara*	Lantana	9.4
Cupressaceae	*Juniperus bermudiana*	Bermudan cedar	9.1
Poaceae	*Melinis minutiflora*	Greasy grass	8.8
Melastomataceae	*Clidemia hirta*	Koster's curse	7.6
Crassulaceae	*Kalanchoe pinnata*	Chandelier plant	7.2
Oxalidaceae	*Oxalis corniculata*	Creeping sorrel	7.2
Cyperaceae	*Pycreus polystachyos*		6.4
Cactaceae	*Opuntia stricta* var. *dillenii*	Red tungy	6.0
Cyperaceae	*Kyllinga brevifolia*		5.9
Poaceae	*Sporobolus africanus*	Cape grass	5.8
Poaceae	*Paspalum scrobiculatum*	Cow grass	5.3
Bignoniaceae	*Tecoma stans*	Yellow boy	5.2

[1]The abundance score is the sum of the individual DAFOR values for each grid cell, averaged by the number of cells on the island.

to make the data sets reasonably comparable is to base the estimate of range size on the proportion of grid cells in which each species occurs (P). The change in range is then calculated as follows:-

Change index = $P_{recent} - P_{Duffey}$

A strongly positive value indicates a large range expansion and a strongly negative value indicates a large range contraction. These change indices reveal some striking differences between the current flora and that of 1958 (Table 14). Five of the most common species on the island today, all now important community dominants (at least locally), were not recorded at all by Duffey. This not only indicates extremely rapid spread, but also a substantial change in the island's ecology. Of these new invasions, only that of Mexican thorn has been reasonably well documented. According to popular opinion, the species was introduced as a shade tree during the construction of Two Boats village in the 1970s, and subsequently expanded rampantly across the surrounding area. Whilst this story is probably largely true, Duffey collected specimens of what he named *Acacia albida* from Ascension, and these appear to be misidentifications for *Prosopis juliflora*. It is therefore likely that a few plants were present some 20 years earlier, possibly providing the inspiration for use as an ornamental in Two Boats. Tree tobacco *Nicotiana glauca* was probably first noted in the late 1980s or early 1990s, but its rapid growth and abundant seed set have enabled it to colonize many parts of the island in just 20 years. It is now extremely abundant on some dry, open slopes including important natural sites such as the Devil's Cauldron. In contrast, the arrival of blueweed, lantana, and tropical heliotrope, and their subsequent spread have gone virtually unnoticed.

Table 14. The species exhibiting the greatest changes in distribution since Duffey's 1958 survey, as indicated by the change index. The top 15 colonists are listed, and the bottom 5 species to have lost ground.

Family	Species	Change index	No. squares (1958)	No. squares (2008)
Asteraceae	*Ageratum conyzoides*	0.810	0	120
Verbenaceae	*Lantana camara*	0.628	0	93
Fabaceae-Mimosoideae	*Prosopis juliflora*	0.608	0	90
Boraginaceae	*Heliotropium curassavicum*	0.520	0	77
Solanaceae	*Solanum nigrum*	0.471	4	81
Solanaceae	*Nicotiana glauca*	0.466	0	69
Euphorbiaceae	*Euphorbia hirta*	0.354	7	72
Fabaceae-Mimosoideae	*Leucaena leucocephala*	0.354	2	58
Poaceae	*Enteropogon mollis*	0.310	0	46
Asteraceae	*Sonchus oleraceus*	0.296	4	55
Poaceae	*Eragrostis amabilis*	0.290	5	57
Bignoniaceae	*Tecoma stans*	0.276	9	66
Rubiaceae	*Spermacoce verticillata*	0.266	2	45
Molluginaceae	*Mollugo verticillata*	0.263	0	39
Papaveraceae	*Argemone mexicana*	0.257	20	94
Euphorbiaceae	*Euphorbia origanoides*	-0.101	10	13
Asteraceae	*Conyza bonariensis*	-0.121	20	38
Poaceae	*Eriochloa procera*	-0.122	10	10
Poaceae	*Paspalum conjugatum*	-0.137	9	5
Poaceae	*Cynodon dactylon*	-0.196	15	13

The speed and extent with which plant communities are changing on Ascension marks it out as one of the most dramatic examples of island colonization in the world. In addition to the five very recent colonists, similar dramatic expansions have occurred with yellowboy, *Spermacoce verticillata* and seedwork acacia *Leucaena leucocephala*. All of these species now form very extensive stands, particularly on the north slopes of Green Mountain, although the former two are more widespread. Whereas yellowboy and *S. verticillata* are pioneer colonists of open ground, seedwork acacia forms dense woodland, often with a thick understorey of another increasing alien species, chandelier plant *Kalanchoe pinnata*. The remaining species on the "increasing" list in Table 14 are all dryland weeds, which reflects the continuing development of vegetation cover across the lower altitudes.

The general pattern of increasing species densities has been witnessed over almost the entire island (Fig. 2). Despite using larger grid cells, Duffey recorded fewer than 10 species over the major proportion of the lowlands, whereas today, such extremely species-poor areas are limited to the north and south coastal fringes. Here, is still possible to find expanses of lava flow which remain almost totally barren, although the extremely hardy grass *Enneapogon cenchroides* is normally present in a few rocky crevices where a little soil has accumulated. This initial establishment may ultimately help to improve the conditions for other species. Such extreme barren areas were probably much more extensive during Duffey's visit, although this level of detail necessary to assess this is not provided.

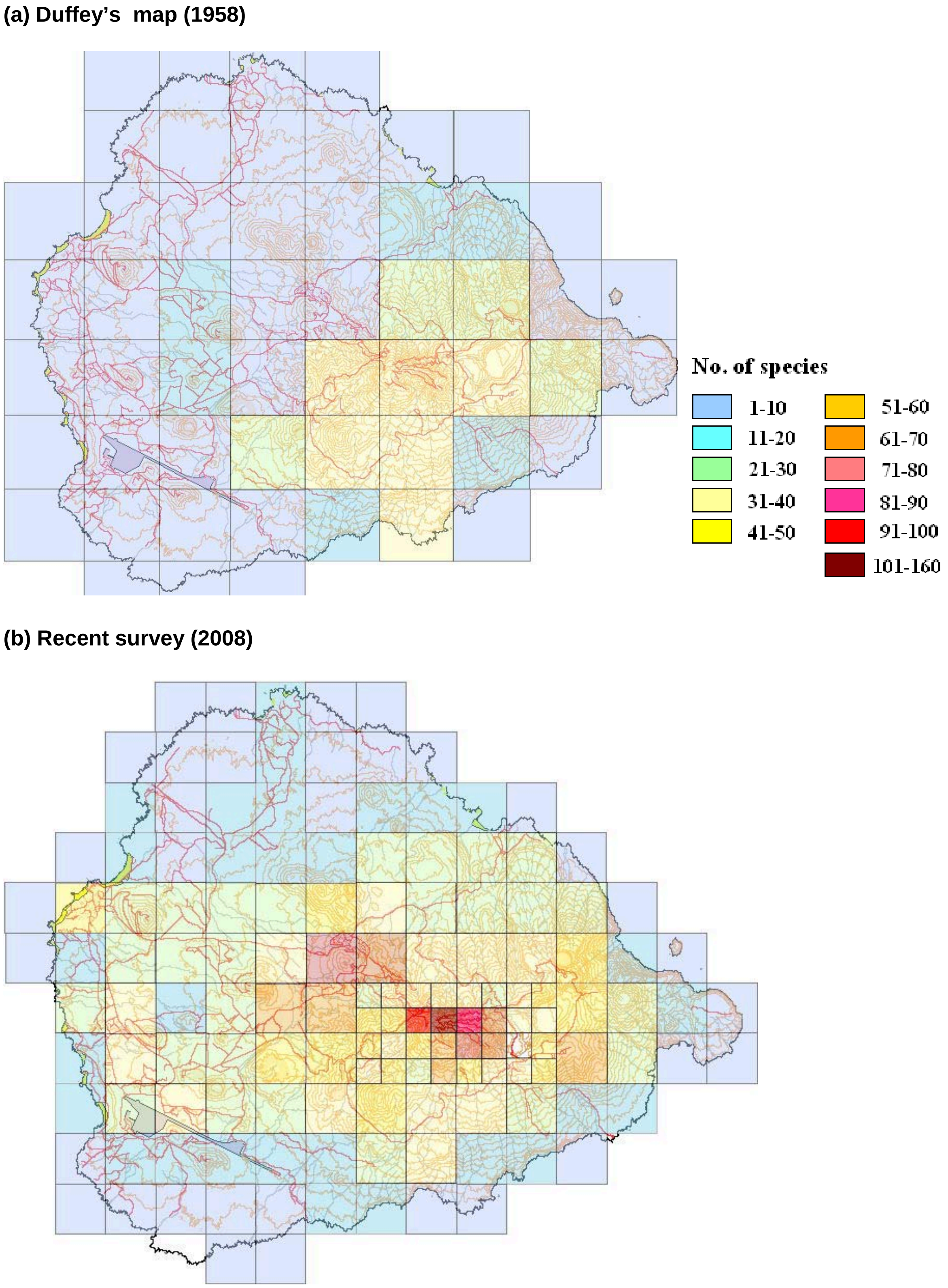

Figure 2. Species density maps to show the number of species in each grid cell on Ascension. (a) redrawn from the data of Duffey (1964) using a mile grid; (b) according to the recent survey which employed a km grid. The intensity of colour indicates the number of species recorded, from blue (few species) to red (many species).

The increase in diversity has been most extreme on Green Mountain. The major habitat changes here over the past 60 years appear to have involved a gradual loss of pastureland and its replacement by dense, unmanaged scrub and forest. Although feral sheep are still common, pasture is no longer actively maintained and the last cattle died-out within the previous decade. Extensive grassland is now only found on parts of the lower slopes. At higher altitudes, numerous new tropical weeds have now established a foothold, although many are clonal forest species which do not appear to be well-dispersed and remain confined to small areas. The major influx has been focused around the Mountain Road and buildings surrounding the Red Lion, which suggests that the colonists have mostly been brought-in by humans, often for garden ornamentals or occasionally as agricultural weeds. Whereas Duffey identified less than **50** species around the summit, there are now **139** species more-or-less naturalized in the 0.5 × 0.5 km grid cell surrounding the Red Lion alone. The density is markedly lower on the eastern slopes.

There have been no range decreases of the spectacular magnitude seen for the expansions, but a few species have experienced moderate range declines (Table 14). Two of the most pronounced are of former pasture weeds, wire grass *Cynodon dactylon* and t-grass *Paspalum conjugatum*, now largely outcompeted by more aggressive grasses such as cowgrass *Paspalum scrobiculatum*, and dense alien scrub. Populations of the only formerly widespread endemic, the St. Helena spurge, have also dwindled. The decline in fleabane *Conyza bonariensis* is somewhat surprising, as there appears to be plenty of suitable habitat remaining and the pattern contrasts sharply with the rapid colonization of the species on St. Helena.

Ultimately, the evidence points towards a massive increase in colonization by alien plants. The number of wholly new species found in the recent survey has inflated the historical list by more than 20%, which in itself is very substantial. However, this assessment compares records assembled over a brief time period with those compiled throughout the course of history. As not all species would have been present at any one time, the year-by-year change is likely to be larger. Overall, Duffey recorded **103** species on Ascension Island, which is less than **50%** of the latest figure, and the increase per unit area may be even larger. Set against this, Duffey was working alone and fitted both a botanical and an invertebrate survey into a comparable time window to that available to us. It is inevitable that his recording effort would have been less, and access to identification material was also more restricted, meaning that some unidentified taxa may have been overlooked. Nevertheless, the inclusion of a number of very rare species in his records suggests that the survey was indeed thorough, and the discrepancy in recorder effort is unlikely to bias the conclusions to a great extent.

Approximately **53** newly-recorded species have emerged in the recent survey, although as not all were flowering or fruiting, some were not identified to species level. In a few cases, it is likely that small populations have been present for some time and records may exist of their original planting, but these are either lost or have yet to be uncovered. For example, the impressive, mature trees of *Araucaria bidwillii* are clearly quite old, but relatively inconspicuous in dense forest on Green Mountain. Others such as drooping prickly-pear *Opuntia monacantha*, which is well-established along the Mountain Road, are likely to have been mis-named as more common species in the past. Oriental hawk's-beard *Youngia japonica*, a common weed in upland areas, has perhaps been classified as both wild lettuce *Lactuca serriola* and nipplewort *Lapsana*

Table 15. Species newly-recorded for Ascension in the current survey.

Family	Species name	Common name	Status
Aizoaceae	*Aptenia cordifolia*[1]	heart-leaved ice-plant	Adventive
Amaranthaceae	*Amaranthus lividus ssp. polygonoides*[1]		Naturalized
Anacardiaceae	*Schnius terebinthifolius*[1]	Wild mango	Naturalized
Araceae-Aroideae	*Epipremnum aureum*[1]	Devil's ivy, money plant	Naturalized
Araucariaceae	*Araucaria bidwillii*	bunya pine	Wild planted
Asteraceae	*Centaurea* sp. [1]		Adventive
Asteraceae	*Chondrilla juncea*[1]	skeletonweed	Naturalized
Asteraceae	*Eclipta prostrata*[1]	false daisy	Adventive
Asteraceae	*Anthemis* sp. [1]		Naturalized
Asteraceae	*Galinsoga parviflora*[1]	gallant soldier	Naturalized
Asteraceae	*Osteospermum calendulaceum*[1]		Adventive
Asteraceae	*Senecio sylvaticus*[1]	wood groundsel	Naturalized
Asteraceae	*Youngia japonica*	Oriental hawksbeard	Naturalized
Cactaceae	*Opuntia monacantha*	drooping prickly-pear	Naturalized
Callitrichaceae	*Callitriche peploides*[1]	matted water-starwort	Naturalized
Caryophyllaceae	*Corrigiola littoralis*[1]	strapwort	Naturalized
Caryophyllaceae	*Herniaria glabra*[1]	smooth rupturewort	Naturalized
Caryophyllaceae	*Stellaria media*[1]	common chickweed	Naturalized
Crassulaceae	*Kalanchoe daigremontanum*[1]	mother-of-thousands	Naturalized
Cucurbitaceae	*Sechium edule*[1]	chow-chow	Adventive
Cupressaceae	*Cupressus lusitanica*	Mexican cypress	Wild planted
Cupressaceae	*Cupressus macrocarpa*	Monterrey cypress	Wild planted
Cyperaceae	*Carex sp.* (aff. *C. bigellowii*)		Naturalized
Cyperaceae	*Carex sp.* (aff. *C. muricata*) [1]	prickly sedge	Naturalized
Cyperaceae	*Cyperus owanii*		Naturalized
Cyperaceae	*Cyperus rotundus*[1]	nut sedge	Naturalized
Euphorbiaceae	*Euphorbia serpens*[1]		Naturalized
Euphorbiaceae	*Euphorbia sp.* (possible hybrid) [1]		Naturalized
Euphorbiaceae	*Euphorbia sp.* (possibly *E. repens*) [1]		Adventive
Fabaceae-Faboideae	*Trifolium repens*[1]		Adventive
Flacourtiaceae	*Dovyalis caffra*[1]	kei apple	Wild Planted
Juncaceae	*Juncus capillaceus*[1]	bullgrass	Adventive
Lamiaceae	*Coleus sp.* (possibly *C. amboinicus*) [1]		Adventive
Malvaceae	*Sida rhombifolia*[1]		Adventive
Myrtaceae	*Eucalyptus robusta*		Wild planted
Nyctaginaceae	*Boerhavia diffusa*		Probably native
Oleandraceae	*Nephrolepis biserrata*	giant sword-fern	Naturalized
Phyllanthaceae	*Phyllanthus amarus*[1]		Adventive
Pinaceae	*Pinus roxburghii*	Chir pine, Imodi pine	Wild planted
Poaceae	*Bothriochloa insculpta*[1]		Adventive
Poaceae	*Digitaria sanguinalis*[1]	common finger-grass	Adventive
Poaceae	*Enteropogon mollis*[1]		Naturalized
Poaceae	*Pennisetum clandestinum*[1]	kikuyi	Naturalized
Poaceae	*Pennisetum macrourum*[1]	thatching grass	Naturalized
Poaceae	*Pennisetum purpureum*[1]	elephant grass	Naturalized
Poaceae	*Tragus mongolorum*[1]		Adventive
Pontideraceae	*Pontederia cordata*[1]	pickerel weed	Naturalized
Portulacaceae	*Portulaca* sp. (possibly *P. pilosa*) [1]		Adventive
Rhamnaceae	*Sageretia subcaudata*[1]		Naturalized
Scrophulariaceae	*Veronica agrestis*[1]	green field speedwell	Adventive
Sterculiaceae	*Turnera subulata*[1]	white alder	Adventive
Urticaceae	*Forsskahlia* sp. [1]		Adventive

[1]Species unlikely to have been previously recorded under a different name or overlooked.

communis by previous authors, whereas hogweed *Boerhavia diffusa* is potentially a native species which has long been confused with its St. Helena compatriot *Commicarpus helenae*. However, at least **41** of the total are likely to be genuinely new records. Most of these are ruderal weeds and some remain as very rare adventives which are relatively unlikely to establish, but a few have the potential to become more serious threats. In particular, the vigorous clonal grasses kikuyu *Pennisetum clandestinum* and thatching grass *Pennisetum macrourum* are strongly patch-forming and have spread rapidly elsewhere, notably on St. Helena. There are also at least two patches of wild mango *Schinus terebinthifolius* and one of bullgrass *Juncus capillaceus*, both of which have been devastating on Ascension's sister island. Dense thickets of the slightly thorny shrub *Sagerettia subcaudata* are already widespread on Green Mountain, and the sedge *Cyperus owanii* is locally dominant around the NASA site and the top of Cricket Valley in the south-east.

The overall changes in the higher taxonomic composition of the flora reflect very closely those observed on St. Helena (Table 16). Ferns and allies (Pteridophyta) comprised an exceptionally high proportion of the original native assemblage, but the major influx of aliens has been heavily in favour of monocotyledonous and dicotolydonous species. The resultant proportions of the major plant groups is now almost the same as that on modern day St. Helena, and indeed, **127** species (just over half of the total flora) are shared with the latter.

Table 16. The higher taxonomic composition of the native Ascension Island flora compared with that of the introduced flora according to the current survey (2008).

(Sub-)class	Natives	Introductions (2008)
Pteridophyta	43.4%	2.8%
Gymnospermae	0%	2.8%
Dicotyledonae	21.7%	62.6%
Monocotyledonae	34.7%	31.5%

Impacts and Issues

St. Helena

Ecosystem effects of plant invasions

Many of the most serious and widespread problems on the island are caused by highly aggressive, community dominants. These are species which have evolved in productive tropical environments where they compete vigorously with numerous other fast-growing species, and as such are predisposed to overwhelm delicately-balanced, species-poor island floras. As they are naturally dominant, they also play a key role in determining the functioning of the affected ecosystems. For example, they may affect the degree of canopy shading, the amount of water abstracted from the soil, the amount of leaf litter produced and its rate of decay, the nutrients available for other species and the degree of soil erosion (Ehrenfeld, 2003). Some species produce toxins in their roots or fallen leaves which inhibit the growth of competitiors (allelopathy), or may increase the fire risk to the habitat if they produce large amounts of dry, dead wood and litter (Callaway & Aschehoug, 2000; Mack *et al.*, 2000). Such invaders therefore can have profound and subtle effects on the overall environment, and create wholly new conditions. Within these modified habitats, native plants face a challenge to co-exist, and other introduced species may be better suited to colonize, thus magnifying the overall changes. The effects are equally felt by other inhabitants of the ecosystem. For example, the amount of food available for insect pollinators (pollen or nectar), and the times of the year when it is present, may be drastically altered. Since many herbivorous insects are adapted to feed on specific species, the new food sources may be unsuitable, with the result that native invertebrates are heavily impacted. There may be few introduced species to take on the vital roles they fulfil, such as pollination, checking the spread of competitive plants and aiding decay processes in the soil (Lyons & Schwartz, 2001).

Figure 3. *Schinus terebinthifolius* invasion along a water-course in Briar's Gut.

The most obvious example of such a modifying influence is *Schinus terebinthifolius*. It is a very vigorous tree or shrub, spreading rapidly by suckers or by fruit dispersed by birds, and is dominant over large parts of mid levels of the island. One of its main advantages is the striking flexibility in growth strategy. Elsewhere in the world (especially in Florida) it has invaded water-courses widely, and thrives best here, forming exceptionally dense, impenetrable thickets where almost nothing else grows. The canopy may be so dense that the understorey is in almost total darkness (Fig. 3). However, it also displays an exceptional ecological flexibility, and can be almost as successful on arid, open hillsides where is grows as a shrub, sometimes very low-growing in windswept-areas. Here the impact on the environment may be more subtle, but since the changes happen over a long time period some of consequences may have been largely unappreciated.

There are clear indications that the widespread invasion of the island by non-native species has had profound effects, some of which are clearly negative, although the exact extent to which non-native species can be held to account is uncertain. Climatic changes, heavy grazing (formerly by goats and now by rabbits) and increased human disturbance are likely to be other important contributors, and there is insufficient information to evaluate the importance of the various contributions. For example, the presence of flax over much of the uplands is believed (widely but apocryphally) to be important in water storage in the uplands. However, flax leaves persist for a long period and their litter decays rather slowly. Compared with the soft, humus-like soils underlying the tree fern thickets which they replaced, the water storage capacity may arguably be much poorer, and therefore the flax plantation may have been a major factor in the general desiccation of lowland water courses.

Figure 4. Massively eroded areas such as this one in Fisher's Valley may have been encouraged by the loss of balanced native ecosystems at the expense of species-poor alien-dominated ones.

One of the consequences of the dramatic changes in ecosystems is that there may be relatively few candidates in the native or introduced species pool which are available to "fill the gaps" of the many niches which are required to create a fully-functioning ecosystem. The consequence is an unbalanced, species-poor habitat. In some cases there may be insufficient ground cover to hold the soil together. Thus, erosion, a serious problem in some areas (Fig. 4), is another factor which may have been at least partially increased by the spread of non-native plants.

Creeper *Carpobrotus edulis* is dominant over much of the Crown wastes and is widely regarded as being a valuable benefit, providing protection against erosion. However, creeper forms very extensive, smothering mats which are interspersed with a thin layer of poorly-decayed, salt-rich litter, and provide a very hostile environment for other species (Fig. 5). By suppressing secondary colonization, they effectively inhibit the processes of succession to stable, more productive vegetation types. Therefore, although ensuring important ground cover, creeper stands remain an unbalanced, very low-quality habitat.

Figure 5. Creeper *Carpobrotus edulis* at Horse point: a low-quality habitat with little secondary colonization

African fountain grass - A recent invader

The recent arrival of *Pennisetum setaceum* (African fountain grass) is a good example of a community dominant which is likely to have pronounced and sometimes subtle long-term effects on the ecology of St. Helena. It is a vigorous grass which spreads extremely quickly via light, wind-blown seed. It currently covers many hectares of previously dry, sparsely-vegetated coastal hillside with dense, tussocky stands. Since Quentin Cronk, the last major botanist to work on St. Helena, failed to record it as recently as the early 1990s, it seems likely that the considerable area of habitat has been colonized in little more than 10 years, and outlying populations are now found as far east as Sandy Bay and Sugarloaf. Although the grass could well invade much of the lowlands, its impact is difficult to assess. Whilst providing much greater vegetation cover than previously witnessed and therefore reducing erosion considerably, there may also be less desirable consequences. These areas have probably always been relatively sparsely-vegetated, and the effect on lowland hydrology remains unevaluated. For the first time, brush fire may become a real risk, as it has done in Hawaii following the invasion of the same species. The dense ground cover also provides little room for other species to germinate (Fig. 6). The result is that the areas become a virtual monoculture, with even such vigorous colonists as *Opuntia* spp. (tungy) being excluded. This may result in extremely low biodiversity, the extensive loss of further dryland native populations, and providing little opportunity for the processes of succession, which would allow more mature, stable habitats to develop in suitable locations.

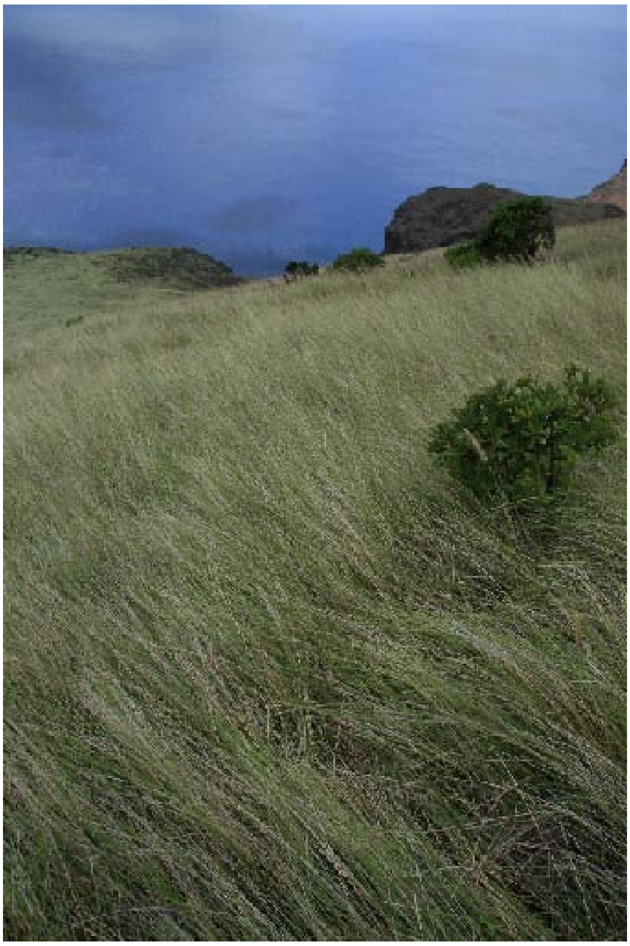

Figure 6. Extremely dense and extensive stands of *Pennisetum setaceum* on High Hill.

Wetlands

The impact of plant invasions differs in severity depending on the habitat concerned. Lowland wetland areas, which on St. Helena mainly comprise semi-permanent valley streams, are almost certainly the most heavily affected. Such wetlands are rare on the island, and are extremely sensitive to external factors, such as changes in hydrology or pollution events. If any endemic aquatic plant species ever existed on St. Helena no record of them has remained, and only a few other natives are specialized to these habitats. Despite this, a characteristic community has developed, comprised of both native and long-established alien marshland species such as *Cyperus laevigatus*, *Isolepis prolifer*a, *Apium graveolens*, *Polypogon* spp., *Cotula coronopifolia* and *Colocasia esculenta*. This is a rich community, ideally composed of a series of fragmented habitat patches, mixing both open water and tall emergent vegetation. Sadly, however, little more than tiny patches persist. The only remaining extensive areas are along Fisher's Valley and, to a lesser extent, along Shark's Valley, although the latter may well be lost to development as part of the proposed airport development. Aggressive invasive species are undoubtedly a major cause of the deterioration, with a number of clonal emergent species present which can form large, dense stands along waterways, stagnating the flow of water and increasing evaporation (Fig. 7). They include the following:

Schinus terebinthifolius	Wild mango
Arundo donax	Giant reed
Echinochloa pyramidalis	
Paspalidium gemminatum	
Pennisetum macrourum	Thatching grass
Pennisetum purpureum	Elephant grass

Wetlands are important as a source of fresh water, and occasionally as the home of other rare species such as the moorhen *Gallinula coronopus* population along Fisher's Valley. The aquatic invertebrate fauna of the island is poorly known. The most high profile endemic species, the St. Helena dragonfly *Sympetrum dilatatum* is probably now extinct, with predation by the introduced grass frog widely regarded as the culprit, but it is likely that the extensive loss of habitat played a much more important part in its demise.

Figure 7. Lower Fisher's Valley, heavily clogged with thatching grass, *Pennisetum setaceum*.

Vines

Aside from the major community dominants, less abundant species can also form a considerable threat to the functioning of ecosystems. Amongst these, vines present their own special problems which have yet to be fully evaluated. Species such as morning glory *Ipomoea indica* evolved in tropical forest, adapted to colonize gaps in the canopy. *Ipomoea indica* is fast growing, and uses its ability to scramble over other species to form large, smothering patches over a short period of time. In natural environments, such areas are not a problem as they are only short-lived – the forest canopy naturally closes-in after a number of years and the colony dies-back, surviving in other tree gaps elsewhere. However, where such species have been introduced to different environments, there is little to check the spread and large patches can build-up. This can be seen to spectacular effect in Rockwater Gut, Sandy Bay, where morning glory and *Pithococtenium crucigerum*, another vine with similar ecology, combine to form an extensive sprawling patch, smothering tall forest to the exclusion of most other vegetation (Fig. 8). Fortunately, the seed-set and dispersal ability of such species on St. Helena does not appear to be great and intrusive stands of this nature are rare. But it is not yet known whether they are likely to spread in the future, which could be damaging in the lusher parts of the island. Only regular monitoring of the threat can assess whether this is likely, so that action can be taken before a serious problem should develop.

Elsewhere, vine species are likely to cause less conspicuous but more immediately problematic populations. Their growth strategy means that they are able to creep through even dense vegetation with considerable success, and they include a few species which are genuine threats amongst the dense native forest in Diana's Peak National Park. Mexican Creeper *Maurandya erubescens* and small fuschia *Fuschia coccinea* are currently both very local in this area, but have the ability to spread quickly and could become insidious weeds if allowed to do so. Removal is also extremely difficult. It may be impossible to access the infestations without trampling sensitive habitat. The long, trailing stems regenerate easily if not removed entirely, and since they become attached and entangled with the surrounding vegetation it is extremely difficult to do this without damaging branches or the delicate covering of critical rare mosses and ferns which covers the trees and shrubs.

Figure 8. The extensive patch of *Pithocotenium crucigerum* and *Ipomoea indica*, Rockwater Gut

Vine-like plants are equally pernicious in lowland forests. The familiar blackberry *Rubus pinnatus* rapidly fouls paths with the thorny, trailing stems which tear at clothes and skin. Blackberry was an early introduction for its fruit, but ironically produces insipid berries which are inferior to many of the similar species cultivated elsewhere. Attempts to eradicate it in the mid 1800s were unsuccessful, although the population was greatly reduced and is now building-up again. A recent colonist may prove to be even more problematic, and has become a serious nuisance in a number of sub-tropical parts of the world. Trailing asparagus *Asparagus densiflorus* appears to have been introduced as a garden plant but has become well-established in the wild, especially in Briar's Gut and Alarm Forest. The red berries are readily dispersed by mynahs, and the plant produces large numbers of extremely persistent white bulbils, which can survive clearance attempts and make it the plant very difficult to eradicate. Although already abundant, this is a species which is only likely to spread, and if efforts are not made to control it at this stage it is likely invade much more widely.

Socio-economic issues

Ecological deterioration caused by invasive plants has far reaching economic costs (Pimentel *et al.*, 2001; Pimentel *et al.*, 2005), although these are notoriously difficult to evaluate because it is impossible to know definitively how much less expenditure would be necessary if the aliens had never been introduced. Direct impacts on the island are less than they might have been if there was more of a goal to achieve self-sufficiency, when effects on agriculture and forestry would be felt more acutely, although with current moves to reduce the dependency of the island on subsidies, such issues may become more critical in the future. Despite this, routine maintenance activities, such as erosion control, water storage and vegetation clearance are clearly associated with on-going costs. The loss of spectacular habitats, such as native tree fern thicket and valley streams, together with the persistent management of troublesome weeds such as brambles (*Rubus* spp.) which can overgrow paths and impair views, is likely to detract from the tourism value of the island in the long term.

At present, agriculture and forestry are indeed the sectors which experience the most evident financial penalties from invasive species. Since livestock farming occupies a significant number of people, including many very small businesses run on restricted profit margins, pasture weeds tend to have the most critical effects on livelihoods. A number of such weeds affect the quality of grazing (e.g. wild coffee *Chrysanthemoides monilifera*, Bermudan cedar Juniperus bermudiana and Lantana *Lantana camara*), although the “big three” are furze *Ulex europaeus* (Fig. 9), whiteweed *Austroeupatorium inulaefolium* and bullgrass *Juncus capillaceus*. Unfortunately there is no easy solution to the problems, and any management will inevitably be on-going and relatively expensive. These species are very widespread, and can only be reliably removed manually which is laborious, or by spraying, which is dangerous if performed incorrectly and therefore requires skilled employees, which are currently in short-supply. All of the weeds require open, disturbed ground to colonize, and are sensitive to

Figure 9. Neglected pasture at Longwood, heavily infested with furze, *Ulex europaeus*.

grazing as seedlings, but can establish rapidly when a window of opportunity becomes available. Such situations often occur when even small patches of ground are heavily grazed and then neglected for a period of 1-2 years during the course of routine stock management. Once a few plants are established, these become new sources of seed to spread the colony further, and as they shelter the neighbouring area from further grazing, may enhance the establishment of other weed species (e.g. whiteweed often gains a foothold amongst furze patches).

Whiteweed – a case study

Whiteweed provides a particularly good illustration of the difficulties posed by weed management. It produces large numbers of seed which are wind-dispersed, probably often for a considerable distance. The seeds can germinate rapidly where the ground has been disturbed, but will remain viable in the seed bank for several years if conditions are unsuitable. The growth rate is extremely rapid, and extremely dense, monocultural stands can appear within a season, reaching 2-3 metres by the 2nd year. Whiteweed occurs in a wide range of habitat types (Fig. 10), especially in upland forestry plantations where it can impede access for forestry operations (of eucalyptus, Cape yew, blackwood and pine), although it is also common in upland pasture and in gaps amongst the flax cover.

The densest populations normally occur under woodland or flax canopies. Although not always problematic here, these areas represent the largest reservoirs of propagules for wind-blown seed to reach new sites. Some of the reservoirs are almost inaccessible, and they ensure a massive potential for recolonization to pasture almost immediately after any previous infestations have been removed. Whilst relatively rare in highly sensitive native tree fern thicket and cabbage tree woodland, it remains a significant problem

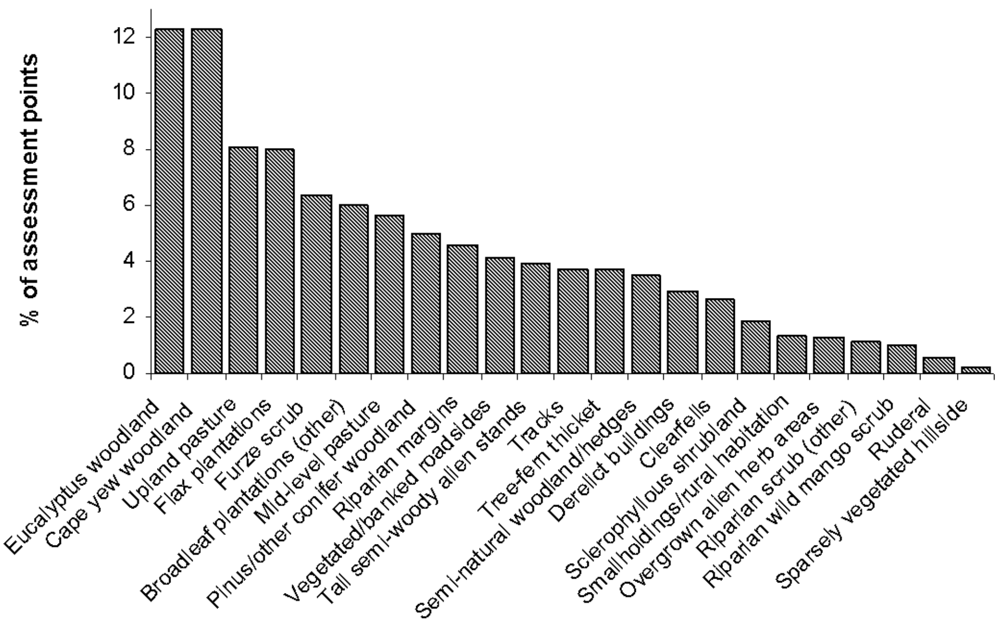

Figure 10. Habitat preferences recorded for whiteweed, *Austroeupatorium inulaefolium*. Each of the habitats where the species was recorded during community assessment point surveys is listed, and bars indicate the % of cases in which they occurred there.

here as it can rapidly colonize recently-cleared areas. Restoration and clearance operations therefore carry a substantial risk as they can allow new populations to infiltrate. Furthermore, whiteweed is a roadside weed on the wetter part of the Peaks, and may spread along these connected invasion corridors. A recent estimate of the costs of eradicating whiteweed, presented to the St. Helena legislative council, suggested a sum of at least £2 million, spread over minimum of 30 years.

Positive benefits

Whilst a general negative message is disseminated to the public about invasive species, it is important to retain a balanced view of the issues. We now have to live in a world where invasive species are part of the normal course of life. There is no possibility or returning to an idyllic, pristine environment, nor would this necessarily be practical for a modern inhabited island.

Introduced plants are vital as crops, and provide a range of materials including timber, fibres and fuel. Indeed, many of the characteristics of successful invaders, such as a fast growth rate, resistance against pests and abundant fruit production, make them ideally suited for harvesting. Although ornamental garden plants are a major global source of invasive species, they remain essential to provide a more attractive living environment. At present, St. Helena is economically heavily-dependent in imports and there is little demand for natural products. However, there remains the potential to create markets which may offset the costs associated with management. Often, relatively light, but ongoing control activities may be sufficient to keep a species in check. Only when there is no incentive to carry out the such tasks is the species regarded as a troublesome weed rather than an asset. Clearly, establishing suitable enterprises around the products of invasive species is not a straight-forward task and may be beset with a range of political and logistical obstacles, but if invasive control ultimately becomes a pressing need, then the imperative to create incentives may be much stronger. For example, the removal of a *Schinus terebinthifolius* thicket for firewood may be laborious and difficult, but the overall cost and effort required may compare favourably with that required to plant, maintain and harvest a stand of pine according to standard forestry practices.

Ecologically, invasive species now perform important roles on St. Helena. Several species are vital in the drylands to preventing erosion and are beginning to form self-sustaining communities, where pioneers adapted to colonize bare ground are succeeded by longer-lived assemblages, eventually leading to woodland. Even the much maligned red tungy (*Opuntia stricta* var.*dillenii*) is an excellent pioneer, as its open, dispersed stands provide shelter for the establishment of annual and other herbs (Fig. 11).

Given the almost total destruction of the native forests, there would currently be no woodlands without the presence of non-native trees. Some forms of woodland, e.g. the *Erythrina caffra-Cestrum laevigatum* (thorn-inkplant) association, have already taken on a “natural” character, whilst the thorn tree makes an excellent hedging plant and provides high quality forage. Given the paucity of native herbs, the increased diversity which introduced species add to the shrubland understorey provides greater ground cover, more sources of nectar and pollen, and helps to lay down new litter. Sometimes, the type of dense tangle they can produce may be undesirable, but even in re-established native habitats, they could form a valuable supplement to the impoverished

Figure 11. Red tungy *Opuntia stricta* var. *dillenii*, acting as a dryland pioneer and forming islands of habitat for the colonization of other species.

natural flora and achieve a more efficiently functioning ecosystem. Even the extensive alien shrublands of *Schinus, Lantana* and *Pittosporum* are an inevitable part of St. Helena's future. At present they form relatively poor-quality habitats, but there may be potential to improve the quality of the environment if a wider range of alien and some native and endemic species could be encouraged to coexist with them, using the cover they provide to nurture and aid establishment. Since little if any work has been done to investigate the possibility of such "habitat engineering", it may be a productive avenue for future exploration.

Ascension Island

Dryland and coastal habitats

For its entire history, Ascension has been dominated by dry, desert-like plains, which are a characteristic feature of a young, volcanic island in the tropics. Whilst supporting relatively little vegetation, these deserts are not without life, and native communities of small invertebrates have evolved here, little in evidence during the day but foraging in reasonably large numbers at night, particularly during the wetter parts of the year. The ecology of the communities adapted to such harsh conditions is little known. It is also little understood what effect the increasing weed colonization will have on them. Certainly, increased litter and seed production is likely to favour invasive invertebrate species capable of exploiting new feeding resources, and this may in turn provide a food source for predators, which may also impact the native fauna.

In addition to the biodiversity present in the dryland areas, the open desert landscape is spectacular and unique, globally important in ecological and geological terms. It is part of the natural heritage of Ascension, intimately linked to its human history. Therefore, it is incumbent on islanders to preserve a substantial proportion of this habitat in its pristine state.

The ongoing and gradually processes of vegetation colonization are establishing a succession which may lead to the loss of much of the desert in the form we currently know it. At present, the low, sparse weed cover is probably rarely a problem, and it is not known how far such processes will develop on exceptionally barren areas like Donkey Plain. However, the rapid formation of large areas of dry shrubland, especially of Mexican thorn (see below) has clearly already resulted in a loss of large areas of desert.

The two most abundant dryland colonists are blueweed *Ageratum conyzoides* and the desert grass *Enneapogon cenchroides*. Blueweed is rare at coastal level but abundant on the lower hill slopes (Fig. 12), where in a few places, we recorded close to 1 million plants in random assessment points, based on a circle of 40 metre radius. When these densities are extrapolated to encompass the entire population of Ascension, the numbers are clearly huge. Most plants set seed, even if not acquiring sufficient nutrients and water to reach more than a few centimetres in height, annually liberating in enormous quantities of wind-blown seed, which may travel some distance unimpeded over the open terrain and provide further massive colonization potential. *Enneapogon cenchroides* has similar population dynamics, but is more closely adapted to the very barren coastal fringe and the seed may lay dormant for many years awaiting favourable conditions. In both cases, the year of survey was particularly wet, and therefore the estimated numbers are probably an exaggeration of the typical pattern.

Figure 12. Extensive populations of blueweed *Ageratum conyzoides* colonizing previously barren volcanic scoria to the east of the Sister’s Peak range.

Despite this, such years provide the optimum conditions for bursts of further colonization, and the advance is likely to continue for some time.

Whereas blueweed was clearly introduced by man, there is more doubt over *Enneapogon cenchroides*. It was first recorded around the wideawake fairs in the south-east of the island in 1917, and is believed to have spread rapidly since then to now occupy much of the western lowlands. According to one theory, seed may have arrived from mainland Africa on the feathers of the wideawakes, how oceanic seabirds could have acquired it is unknown. If so, then *E. cenchroides* is technically a native, marked-out as a natural colonist and not one brought in by man. This underlines a difficult issue with the management of plant invasions. The arrival of new species and their gradual integration with the island ecosystems over evolutionary time is a key feature of island biogeography. It is not a desired goal to completely halt such processes as they are essential to maintain the vigour and vitality of the island's biome, yet it is ecologically damaging if they continue to occur at the artificial and extremely high rate which we currently see. The criterion of usually adopted (and rarely stated explicitly) is that alien introductions are regarded as non-natural and therefore undesirable whereas natural introductions are regarded much more favourably. But this creates the strange contrast that two widespread colonists of the same habitats, *E. cenchroides* and *A. conyzoides*, may be regarded very differently, despite their apparently similar consequences. Clearly, such a rule has useful merits, but it would be dangerous to regard it as immutable, and a degree of flexibility and common-sense is required to adopt appropriate responses to each issue individually.

Whilst the two species above are good examples of dryland colonists, a number of other species play a role in this process and others, recently established, may contribute in the future. Whereas much of the coastal fringe remained bare until very recently, the widespread advance of tropical heliotrope *Heliotropium curassavicum*, has commenced the succession of even this hostile, marginal habitat. The succulent leaves provide a food and moisture source for sheep during dry periods, thus encouraging them to forage in barren areas where they may sometimes have an adverse effect on native plants, and spread further seeds and propagules on their coats and in dung. Heliotrope is also an issue, along with a few other species tolerant of dessication and salt-spray, on the sandy beaches, which are increasingly fringed with growths including Mexican poppy *Argemone mexicana*, Mexican thorn seedlings, goosefoot *Chenopodium murale*, and tree tobacco *Nicotiana glauca*. In many cases, the expanses are important nesting sites for green turtles *Chelonia mydas*. The vegetation impedes their access, and affects the temperature and moisture retention of the sand, which may influence hatching success. As most of the weeds set abundant seed, regular manual removal may be required, which is both time consuming and requires substantial manpower.

Mexican thorn

The most obvious impact on the dryland landscape comes from the extensive scrub of Mexican thorn *Prosopis juliflora* (Belton, 2008c). These have spread across the lowland plains with alarming speed, although a comparison between the distribution recorded in the recent survey, and that established by analysis of a 2002 satellite image (A. Mills, lodged on the AEIOU GIS system) suggests that no new squares have been colonized over the past six years. Nevertheless, there is little reason to suppose that many of the remaining open areas in the north east and along the south coast of the island are not susceptible to future invasion. A few bushes are currently found dotted along the Waterside wideawake fairs, and it is possible that they will gradually encroach on these important bird breeding grounds, taking advantage of the undisturbed periods when the birds are at sea to establish. Were this to happen, it could constitute a serious threat to the viability of the colonies.

Figure 13. A green canopy of Mexican thorn *Prosopis juliflora* scrub across the previously barren or sparsely-vegetated lowlands near Traveller's Hill.

Although sometimes grazed by donkeys, Mexican thorn is remarkably tolerant of damage and can coppice well. In fact, the foliage is not preferred as a food source, but the nutritious seed pods are much sought by donkeys and sheep, which probably help to spread the seed to remote corners of the island. Thorn scrub can be extremely dense in on the sandier soils around the foot of Green Mountain (Fig. 13), impeding human access and with little understorey vegetation. At present, it is less dense over the more barren, clinker-strewn areas, and in such places the ecological impact may still be relatively small. Such habitats often support a reasonably diverse weed flora, but the shade and excess litter deposited from their fallen leaves enables alien invertebrate communities to develop, mainly dominated by detritivores, especially woodlice (Isopoda) and ants (Hymenoptera: Formicidae). The latter, which are also voracious predators capable of scouring wide areas for food, are likely to be particularly damaging to the indigenous invertebrate fauna. Thus, although currently not particularly problematic at low densities, there is the potential for further threats to develop if these areas become in-filled with scrub. Another potential issue which must now be considered seriously is that of increasing fire risk across the lowlands of Ascension. In combination with species such as *Casuarina equisetifolia*, which now forms forests north of Two Boats, the massive increase in litter and wood (both dead and live) has greatly increased the fire loading across the lowlands (Pasiecznik *et al.*, 2001), to the extent that the environment now resembles that of fire-prone habitats in many other dry parts of the world.

Guava

Whilst Mexican thorn attracts much attention on Ascension because it infests the populated western areas, guava *Psidium guajava* is almost as widespread and perhaps carries even more serious ecological implications. Unlike its western counterpart, guava has been widely established across much of its present range for at least 150 years, and does not appear to be spreading greatly along the coasts although it may have expanded on the upper slopes of Green Mountain. It is a resilient species, growing to a small tree in more humid habitats but spreading to become a low shrub in exposed or dry areas. At many of its locations, it forms extensive, monocultural stands of tough impenetrable branches (Fig. 14). The leathery leaves lay down a thick litter which lies undecayed on the surface of the ground for long periods, suppressing the development of ground cover and inhibiting competition from other woody species. Guava scrub therefore represents a poor-quality, unbalanced habitat. Due to its long persistence, much of the ecological damage was probably inflicted many years ago, and in the remote corners of the island where it is most prevalent, there is now no way of knowing what the original habitats were like. As these areas are much more humid than the rest of the island, they may have been substantially different and could even have contained some native species which were pushed to extinction without ever being described.

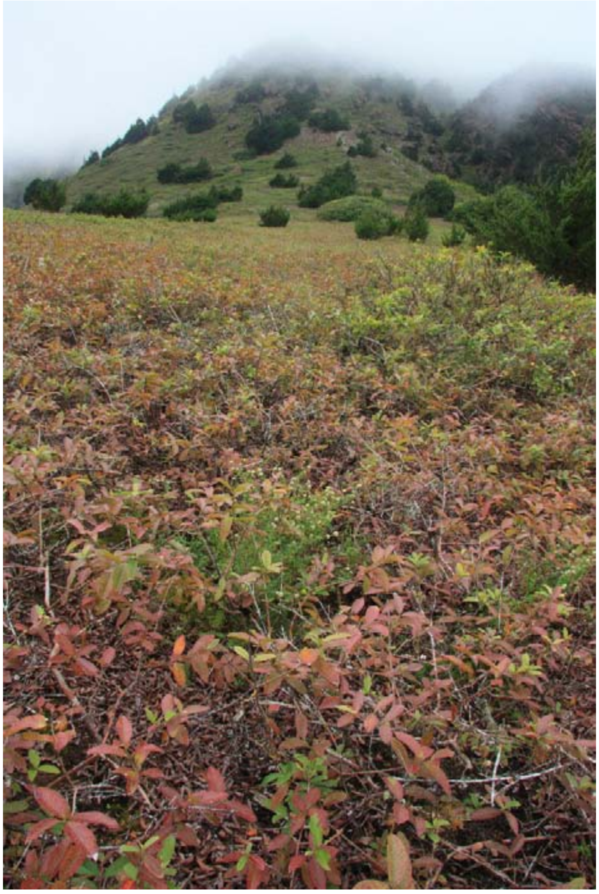

Figure 14. Hillside covered by low guava *Psidium guajava* scrub west of Cricket Valley. The biodiversity of this habitat is extremely low.

Guava fruits in abundance during the winter, and although germination appears to be rather sporadic, it can occasionally establish quite abundantly from seed. On the Mountain, the fruit is good to eat, although harvested by islanders only in small quantities. The shrubby plants at lower altitudes tend to produce astringent fruits which are of little value to humans. They do however provide an abundant resource for rats, which often congregate in large numbers around fruiting stands. Since the successful cat eradication of the late 1990s, rat numbers appear to have increased alarmingly, and they have the potential to become a major environmental problem despite extensive ongoing attempts at control. The widespread presence of guava probably helps to sustain the current expansion. This is a particular problem when guava fruiting occurs during the phase between two wideawake breeding seasons (apparently a 9 month cycle), providing food in sustained abundance for an extended period. Rats also appear to be responsible for dispersing guava seed, and with their current increase, there is a renewed possibility that the population will undergo renewed spread. It currently appears to be extending further down some valleys and is present in patches westward beyond the main range, although due to the lack of previous detailed records it is impossible to assess how long these outliers have been present.

Lower slopes and foothills of Green Mountain

The lower slopes of Green Mountain perhaps constitute the most heavily modified parts of Ascension in recent years. They are located below the lush uplands which have been vegetated for millennia and have long been infested with invasive species, and the inhospitable lowlands. The climate remains moderately cool and humid, thus being well-suited to support vibrant growth. It is not entirely clear what types of habitat occupied these areas in the historical past. Over much of the southern and eastern slopes, much of the land has probably been under extensive pasture since the time of Hooker, but the northern aspects appear to have been open and sparsely-vegetated. In the west, there are extensive complexes of rocky cliffs and boulder fields which still retain a semi-natural character, the crevices dominated by the native fern *Nephrolepis hirsutula*.

When the Ascension Island garrison was largely self-sufficient, prime farmable land was an extremely valuable resource. Much of the suitable area would have been devoted to well-maintained pasture at this time, although even then, the grasslands were probably extremely low in diversity, being overwhelmingly dominated by greasy grass *Melinis minutiflora*. This species is of moderate forage value globally, but was adopted on Ascension because it established much more readily than other alternatives. Today, the area of pure grassland has diminished, but still persists in places where the sward is maintained by intensive grazing by feral sheep. The cover is often fragmented and infested with non-forage species. Scrub encroachment, particularly of guava, has overwhelmed many areas. A few pockets of other types of farming once persisted, with vegetable crops and fruit trees historically maintained at Palmers, and perhaps also at North-East Cottage to a lesser extent. These have provided further colonization nuclei for non-native species. Although guava is perhaps the only produce species to have become widely invasive, others brought-in for ornament and shade, such as seedwork acacia and Persian lilac *Melia azederach*, appear to have spread from these points.

The ecological value of *Melinis* grassland today is unclear. The reasonably dense sward helps to prevent erosion and provides open areas which would otherwise be encroached by denser vegetation. Although supporting relatively little biodiversity, in areas where the grass cover had disappeared, it has largely been replaced by monocultural shrub stands (not only of guava but also of species such as *Spermacoce verticillata* and lantana) which are usually even less diverse. If such grasslands continue to be lost then the likely outcome is further scrub encroachment. As the costs and benefits of this are often considered to be fairly neutral, the trend is currently not seen as a particular issue, but if it ever becomes valuable to re-establish a farming industry on the island in the future, then extensive restoration would be necessary at considerable cost. The sheep and rabbit populations on Ascension are probably higher than they have even been, and both species are largely sustained by grassland areas although they wander much more widely across a variety of habitats. The maintenance of a grazing regime is probably valuable as it helps to suppress further invasion in a range of contexts. However, excessive numbers of sheep are undesirable as they may damage more sensitive lowland ecosystems, spread seed and increase erosion through trampling. Rabbits are even more problematic as they are difficult to exclude. They damage crops, have serious impacts on native populations of *Euphorbia origanoides* (Gray *et al.*, 2009), and have proved to be a serious pest in the habitat restoration area on Green Mountain.

The lower- to mid-slopes of the mountain are increasingly being succeeded to forest. Stands are rarely mixed and the habitats remain species-poor with few under canopy herbs. There are four major forest types in this area, composed of (i) guava, (ii) *Eucalyptus camuldulensis*, (iii) Bermudan cedar *Juniperus bermudiana* and (iv) seedwork acacia *Leucaena leucocephala*. All are probably expanding to some extent, although the *Eucalyptus* woodland is the most restricted, to valleys draining the north side of the Mountain. Bermudan cedar, which was introduced to Weather Post in the 1820s, now covers much of the higher ground between here and the west side of Green Mountain. *Leucaena* forest has clearly extended the most rapidly in recent years, the seeds being produced in abundance and germinating in large quantities. They are perhaps dispersed by sheep, which often shelter under the canopy at night or in wet conditions.

Most of the remaining mid-altitude areas are now occupied by pure stands of scrub, which is probably the least ecologically desirable habitat type, being extremely low in diversity and often impenetrable, which makes the prospects of management very difficult (Fig. 15). In its most extreme form, the consequences can be seen in Cricket valley, which is densely filled with an unpleasant mix of several species, including an extensive stand of red tungy *Opuntia stricta* var. *dillenii*. From the prominence of this species in19th Century reports, it was probably more widespread in the past, when the spread may have been checked by extensive control efforts. A comparison of the current distribution with that implied by Duffey suggests that it may once again be on the increase, and must be considered a potential threat given the invasive tendencies of this species on St. Helena and elsewhere, and its ability to flourish in very dry habitats.

In areas which either never established to grassland, or have subsequently been disturbed and eroded, yellowboy *Tecoma stans* has staged a striking recent wave of colonization. It currently covers large areas of hillside on the lower north slopes of Green Mountain, extending out across the wastes of Bear's Back and in numerous other pockets across much of the island, sometimes even occurring scattered across the almost sterile black lava fields. The rate of spread has been poorly-documented, but is likely to have been extremely rapid. According to anecdotal accounts, the western scoria slopes of Mountain Red Hill have become densely-covered with tall, green vegetation in a matter of a few years, the name therefore no longer seeming appropriate. The long-term ecological implications of yellowboy remain unknown. It is an early-succession pioneer and may therefore help to stabilize almost bare ground. Relatively large amounts of litter are laid-down, thus transforming the habitat substantially. Whether the community will eventually be succeeded by other vegetation remains to be seen. Clearly the population is quite persistent, at least in the short term, and the tall dominant canopy is likely to inhibit encroachment by many other species, ensuring that any changes are slow to develop.

Thus, although the lower mountain slopes are therefore clothed in a patchwork of habitat types, these are all composed of unbalanced, low-diversity communities with little ecosystem functionality. Rather than co-occuring in mixed communities, there is little integration between species. This partly results from the fact that many of the colonists are aggressive community dominants, adapted to out-compete rivals for resources, but may also be a characteristic of the early stages of primordial ecosystem development.

Figure 15. Vigorous shrubland of yellowboy *Tecoma stans*, grading from the edge of *Leucaena leucocephala – Kalanchoe pinnata* (seedwork acacia and chandelier plant) woodland. Both habitat types have recently established on north-west side of Green Mountain.

High altitudes

We know from Hooker's accounts of the mid-19th Century that the upper slopes of Green Mountain were originally swathed in "a carpet of ferns". This was probably the most diverse and lush native community on the island, even though perhaps no more than 10 species occurred regularly around the summit area. The remnants of fern sward which still exist mainly comprise *Christella dentata* and *Histiopteris inscisa*, two species which are possibly part of the original community but are also relatively widespread in Africa and elsewhere. Otherwise, the modern upland environment is dramatically different from that of Hooker's description. Most of the summit area is now clothed in a complex of several woodland, scrub and grassland habitats. In these areas, the communities are often highly productive, dense and comparatively diverse, although as with the habitats elsewhere on the island, they tend to be composed of patches of aggressive dominants, albeit on a much finer scale.

The lush, tropical forest is the most impressive of these habitats, and is probably the most successful legacy of Hooker's revegetation programme. It differs substantially in local character, often depending on the mix of trees which were originally established, but may include a canopy of *Ficus microcarpa*, screwpine *Pandanus utilis* (known locally as breadfruit), Cape yew *Podocarpus elongata* or white olive *Elaeodendron capense* amongst several other species. A tall understorey often fills the gaps, including numerous exotics such as *Clerodendron fragrans*, shell ginger *Alpinia zerumbet*, bougainvillea *Bouganvillea* hybrids and Cretan fern *Pteris cretica*. The taller trees are excellent mist interceptors, and deposit a layer of well-decayed litter which aids in the storage of moisture. The overall habitat is therefore now critical to the hydrology of the mountain, and although the human population no longer relies on indigenous sources of drinking water, the ecological role is vital. Ascension has very few natural drips, and from historical records, it seems likely that those present may have dried-up substantially over the previous century. Paradoxically, this may be at least partly due to

Figure 16. Tropical forest, principally dominated by screwpine *Pandanus utilis*, on the summit ridge of Green Mountain. The canopy acts as an effective mist interceptor, and has developed a healthy community of epiphytic bryophytes.

increased evapo-transpiration from vegetation, although climatic factors may also be important. Regardless, the modern day situation would probably be worse were it not for the presents of these high-altitude forests. Another consequence of mist interception is that the branches provide excellent habitat for a number of epiphytic bryophytes, including several endemic species (Fig. 16), and the tiny endemic fern *Xiphopteris ascensionense* (Fig. 17). It is assumed that the *Xiphopteris* – bryophyte community originally inhabited damp, exposed rock crevices, which have now become a scarce resource due to the encroachment of other vegetation. The new habitat is entirely non-native, but has provided an unexpected refuge which potentially saved some of the community from near extinction.

Figure 17. *Xiphopteris ascensionense*, a recent colonist of the new epiphytic habitat provided by forest near the summit of Green Mountain.

The highest point on Green Mountain is now enveloped by a bamboo forest (species still undetermined). This covers a fairly large area and appears to be spreading slowly, largely through rhizome extension. The bamboo grows to 6-9 metres, and may provide some protection against the wind, further moisture interception, and protection from surface evaporation or erosion. It shelters a few plants of the endangered fern *Marattia purpurascens*, and the stems often accumulate growths of mosses and *Xiphopteris ascensionense*. For this reason, the bamboo is often considered to be an important habitat. However, the ground layer is heavily shaded and generally contains a sparse, rank understorey of approximately only six higher plants (Fig. 18). It competes for important space which would otherwise probably be occupied by more diverse forest, and this would also be likely to support much higher densities of endemic epiphytes.

Figure 18. Bamboo forest near the summit of Green Mountain – a dense and species-poor habitat

The scrublands occupy large areas and may be extremely dense. They are principally composed of a series of aggressive, cosmopolitan species renowned as invasives throughout the tropics. Some are also problematic at lower levels (lantana, guava, Koster's curse and Bermudan cedar), whereas others are restricted to higher altitudes (Madagascar buddleja *Buddleja madagascarensis*, shell ginger *Alpinia zerumbet*, lovechaste *Vitex trifolia* and *Sageretia subcaudata*). Less dominant, but often creeping through dense vegetation, are further pernicious species, notably blackberry *Rubus pinnatus* and raspberry *Rubus rosifolius*. Other potentially smothering vines are present in extensive but localized clonal patches, and could yet spread (e.g. Bengal clock-vine *Thunbergia grandiflora*, *Epipremnum aureum*). In general, the major scrub constituents do not interact greatly and constitute ecosystems of little better quality than those of the lower scrublands. Their dense thickets are very difficult to access and manage, especially because many infestations are on very steep slopes. Furthermore, control is extremely labour intensive: for example, shell ginger can regenerate from ground level to a height of 2 metres in a matter of weeks.

Extensive grassy areas are most abundant on the south and east sides of the summit, and are comprised predominantly of cow grass *Paspalum scrobiculatum* and Cape grass *Sporobolus africanus*, although in a few areas, the taller thatching grass *Pennisetum macrourum* has established. None of these species is favoured by sheep, which is probably the main reason for their success. The lush growth becomes particularly resistant to management when the grass is interspersed with encroaching low scrub species, especially blackberry, where the stems help to bind the sward into a tall, dense mat.

The dramatic change from a low fern sward to a dense patchwork of competitive shrubs, grasses and forest has been devastating for the endemic flora of Green Mountain. Five of the island's six surviving higher plant species are restricted here, mostly to the upper slopes. Of these, the population of the Ascension spleenwort *Asplenium ascensionis* is relatively stable although remaining rather local (largely restricted to a narrow altitude range below on the south side of the summit), and whilst remaining rare, *Xiphopteris ascensionense* is now likely to be increasing due to its recent habitat switch. The remaining three endemics are in a precarious position, and thanks to a loss of most of their traditional habitat, have little chance of recovery without substantial management efforts. The grass, *Sporobolus caespitosus*, is found on exposed basaltic rocks on the weather side of the peak. It is threatened by sheep grazing, and by the gradual in-filling of its habitat by other vegetation. *Pteris adscensionis* is even rarer. Plants are very widely scattered, mostly at mid altitudes across the southern foothills from Mountain Red Hill eastward, although at densities as low as a few plants per km^2, many of which are very small. Little more than 30 reasonably large specimens are distributed between Breakneck and Cricket Valleys. The final species, *Marattia purparascens* is now restricted to diffuse stands on the very steep hillside below the south-eastern summit (Fig. 19). Although several hundred individuals remain and the fern is very robust, this is perhaps the most critical of all. Its habitat is now densely in-filled with grassy scrub. There are virtually no understorey gaps where spores can germinate, and very few young plants are present in the population. It is not known how long individual *Marattia* crowns persist, but with the current lack of recruitment, it may be as little as one or two decades before the natural population begins to plummet sharply towards extinction. Even if the benefits of habitat management are marginal for other reasons, extensive habitat management is clearly necessary if the three critical endemics are to be saved.

Figure 19. Steep hillside on the south-east side of Green Mountain summit. This is the native habitat of *Marattia purparascens*, but is now heavily invaded by dense scrub and grassland.

Introduced species and the threat of hybridisation

The potential for hybridisation is an insidious threat carried by introduced species to endemic or native taxa, especially those that are already rare or vulnerable. Rather than suffering from physical competition, the unique insular gene pool is diluted by the DNA of common species, which in turn may have impacts on the ecological fitness of both parental stock and progeny. In known cases, the alien is generally closely-related to its threatened counterpart to permit the possibility of cross-breeding, but it need not be highly invasive to carry a risk since relatively little pollen transfer is necessary to contaminate numerous individuals. If the hybrid offspring are fertile then repeated back-crossing with either parent can continue to dilute the genetic integrity of the population. Furthermore, hybrids are often more vigorous than the parent, especially when the cross has involved polyploidization (chromosome doubling), and may therefore be selectively favoured in subsequent generations. Hybrids may be difficult to identify as they may superficially resemble one of the parents, and even when clearly different may be ignored as an aberration if their characteristics do not fit known descriptions. It is therefore possible for considerable damage to be inflicted before the problem is recognized.

Thus far, no proven issues of hybridisation have been reported on either Ascension or St. Helena, but it is possible that this phenomenon has played a major part in the extinction of two Ascension endemic plants over the past 200 years. The tufted grass *Sporobolus durus* is taxonomically, morphologically and perhaps ecologically similar to the introduced *S. africanus*, now a very widespread species which is dominant on the rocky hillsides around Weather Post where the endemic was previously recorded. Similarly, Ascension's only native shrub, *Oldenlandia adscensionis*, is closely-related to the widespread invasive *Spermacoce verticilata*. In both cases, it is not unlikely that the two relatives hybridised, and the abundant alien may have simply overwhelmed the native. These cases may represent very real precedents to illustrate the seriousness of the threat.

The 2008 survey highlighted a new potential hybrid which could constitute a further developing threat to the Ascension Island spurge *Euphorbia origanoides*. An unidentified *Euphorbia* was recorded from two localities, close to the Airhead and at Comfortless Cove. This taxon is morphologically similar to the endemic species,

Figure 20. Unidentified *Euphorbia* species, suggested as a possible hybrid between the endemic Ascension island spurge *E. origanoides* (lower inset) and an introduced weedy *Euphorbia*. If this identification is confirmed, the hybridisation could threaten the integrity of the endemic population.

especially in the flowering and fruiting parts, but has a distinctly different growth form: lower and spreading with smaller leaves, and a densely-crowded inflorescence (Fig. 20). Efforts to name the taxon are ongoing, but there is a realistic possibility that it may be hybrid between *E. origanoides* and of the introduced, weedy *Euphorbia* species. Perhaps *E. serpens* is the most likely second parent, but a newly recorded adventive, apparently close to *E. repens*, was also found on the U.S. Base. Both alien and endemic species are all visited by the native Rhopalid bug *Liorhyssus hyalinus* for nectar, which would facilitate cross-pollination.

It remains equally possible that the new taxon is merely a further newly-introduced adventive species and does not constitute a hybridisation threat. Even if it is a hybrid, the risk will be small if the seed is infertile, and/or the introduced parent does not become widely naturalized. However until the biological details have been established, the risk cannot be discounted. If action to resolve the situation is not taken immediately, then a further substantial setback may be inflicted on the already precarious world population.

Socio-economic issues

The unusual social and political structure prevailing on Ascension Island has considerable implications for the conservation and management of the natural environment. The island has no permanent resident population and its human community is therefore composed of workers assembled for employment purposes. Even if many have lived on the Ascension for much of their lives and regard it as their home, the general level of "ownership" of the environment is probably less than in many other small communities. There is no long-term unemployment, and therefore little incentive to generate business by developing private enterprise. The capacity to establish independent farming operations or generate money through ecotourism is consequently very limited. The great majority of food and other consumables is imported, which produces very little requirement to make use of the available land. Even if an attempt to establish a viable farming enterprise was established, the costs associated with returning neglected habitat to agriculture, maintaining fertile soils and controlling pests, would be considerable, at least initially. Large areas of the lowland desert have very little economic value except to military or communications needs, and if not directly restricting access to the public, intrusion may be unfavourable due to security or safety issues. Whilst some operators (e.g. the U.S. military) have funding to conduct their own control programmes, neglected land provides the potential for reservoirs of invasive species to build-up.

Given this combination of circumstances, both the incentive and the capacity for managing the island's ecological problems are heavily constrained. With little land use, there is no great inducement to spend large amounts of money on activities such as scrub removal, which will produce little perceived benefit. Conservation is predominantly funded through the government, and although the small but active Conservation Department carries-out a range of activities, these are necessarily limited to the highest priority tasks. Much of the effort is required to maintain the *status quo* with little spare manpower available to undertake new projects. It is often perceived that there are few opportunities to generate additional income in order to fund further action, or to make this pay for itself in the short-term. Whether creative solutions to these challenges can be found remains to be seen.

A further important barrier in managing Ascension's environmental problems is the lack of an obvious solution to them. The massive level of invasion, and the speed with which it has overwhelmed the island, has created an ecological conflict more extreme than virtually any yet encountered in human history. There are few documented solutions from elsewhere which can be drawn-on, and some of the conflicts are seemingly intractable. Whereas standard practice in other parts of the world may aim to remove invasive species and replace them with well-balanced native communities, this is not an option on Ascension. As little as two centuries ago, much of the island was barren and inhospitable, and a few of the key native species which perhaps provided much of the ground cover (especially the shrub *Oldenlandia ascensionis*) are now extinct. Since the island is now inhabited, we require the environment to support and provide a comfortable living space for the human population, and clearly a return to the original landscape is neither desirable or practical. Many of the newly-formed communities lack diversity and do not contain the range of species fulfilling different functional roles to maintain a well-balanced ecosystem. Yet it would be extremely unwise to encourage the introduction of further non-native species to perform these roles, as the performance of such species is unpredictable, and each represents a potential invasive threat in its own right. Finally, there is a need to integrate the remaining native ecology of Ascension with that of the new, developing ecology, despite the extreme contrast in dynamics between the systems involved.

Despite the conceptual and practical difficulties faced, there remain a few pragmatic reasons for addressing some of the difficult land management issues. Firstly, there are legal obligations to protect endangered species and habitats. Invasive vegetation threatens not only the remnant endemic plant populations, but also the viability of invertebrates, turtles and seabirds, directly or indirectly. Secondly, a level of ongoing maintenance is necessary to keep the island functioning and to provide suitable recreation space, whether this involves clearing paths, removing weeds from around buildings, cleaning beaches or reducing food resources for rats. In both cases, basic management to alleviate such issues may consume a significant proportion of available budgets, but in some cases, more extensive efforts to provide a longer term solution (whether through eradication programmes or engineering habitats to make them less invasible to undesired weeds) may be cost-effective.

Beyond these reasons are less quantifiable factors. Globally, there is currently a move towards sustainability, economic efficiency and reduction of carbon footprints. This may ultimately lead to the necessity for Ascension to become at least partially self-supporting in the future, and to look for ways in which to utilize resources which are currently not economical. If the general state of the environment is allowed to deteriorate today, then such moves will ultimately become much more costly in the long-term. Even now, given the right encouragement, there is much potential for generating greater income, volunteer manpower and public support to progress conservation efforts beyond their current state. Every day when these opportunities are under-exploited carries an ultimate social and monetary cost.

Action for the future

The management of invasive plant issues clearly requires long-term investment and is heavily hindered on the South Atlantic islands by a lack of resources, manpower and expertise. Overcoming such problems requires innovative thinking and a proactive approach, but it is clearly not realistic to expect anything even close to the level of investment necessary to implement all the desired actions. Despite this, it must be considered that a moderately large short-term investment to eradicate a problem before it becomes acute can sometimes be more cost-effective than the sustained mitigation which would be necessary in the long-term. Extensive recommendations have been made elsewhere (e.g. Belton, 2008a, 2008b, 2008c; Pickup, 1999; Royal Botanic Gardens Kew, 1993b), and it is not the purpose of this document to revise such efforts, Instead, the focus is on more general principles, and in particular, where monitoring can contribute to the strategy. It will inevitably be necessary to prioritise a limited suite of activities, but aspirations towards more ambitious long term objectives should not be dismissed, if and when opportunities arise.

St. Helena

The framework of any efforts to tackle invasive plants can be broadly divided into four main areas:

Control of existing problem species

The overwhelming dominance of introduced plant species on St. Helena necessitates that it is not realistic to treat them all as priorities for removal, nor would this be immediately desirable where there is little capacity to replace the existing vegetation. One of the key prerequisites for any clearance programme is the presence of a suitable revegetation strategy, and the ability to implement this quickly. Clearance to open ground, particularly if followed by heavy rains, leaves the habitat vulnerable to erosion which may make it more difficult to re-establish the desired vegetation. Many of the most pernicious invasives, such as whiteweed, are ideally suited to reoccupy recently-cleared land, so inadequately planned projects could ultimately exacerbate the problems they are intended to remedy. In addition to the prior preparation needed, careful thought must be given to the post-removal processes. Thus, the overall list of considerations include the following:

- Plan an appropriate habitat restoration scheme
- Develop a suitable nursery stock to effect the restoration
- Minimize the environmental damage and safety hazards caused by the proposed removal activities
- Carry-out the removal using appropriate techniques
- Restore the habitat as soon as possible
- Remove the clearance refuse in an environmentally-responsible way
- Maximize activities to offset costs by finding markets for the products
- Monitor of the success of the project over a period of several years, and record adequate data to evaluate the approaches used, for future reference
- Ensure that there is some capacity for follow-up activities, to correct any unforeseen problems.

The lengthy list of considerations necessarily adds a significant element to the manpower and costs involved, ensuring even further the need to target the most serious problems carefully. However, it is probably better to target a small number of model schemes than a larger number of poorly-implemented ones.

Whilst basic restoration projects are required to tackle invasive species, the need to consider a wider management strategy is equally important. There is little point in removing a weed infestation if there is a high chance that the species will recolonize in the long-term, rendering the efforts of little value. One important step to prevent this is to make St. Helena a less weed-friendly environment in general. Much potential exists for the development of strategies to achieve such a goal, including the following steps:

• *Eradication of sources of weed propagules on wild or neglected land to remove sources of potential recolonization*
This is a daunting task, as a great many small weed patches exist, many of which are very isolated. However, it is a clearly very important part of a successful control programme, and is aided by the fact that for most species, the number of seeds dispersed tends to decline quite rapidly with distance away from the origin. The dispersal efficiency profile varies substantially from species to species. For furze *Ulex europaeus*, most seed is dropped within a metre of the parent, and even for the most effectively wind-bourne weeds it is surprisingly small. For a species closely-related to fleabane *Conyza canadensis*, Dauer et al. (2006) found that 99% of seed landed within 100 metres of the parent, although this can vary greatly with wind speed and topography, and the few pioneers which reach further than this may still be sufficient to form new populations (some seed was found to disperse for 500 m). However, it offers hope that maintaining a reasonably limited exclusion zone around pastures or other sensitive areas may starve them substantially of incoming propagules. Furthermore, maintaining an effective barrier such as a dense hedge, may also intercept much of the potential seed rain.

• *Rapid removal of satellite colonizations, which form the nucleus of new centres of colonization*
Where small numbers of invasives do manage to become established away from their main population centres, in areas which are potentially suitable for further spread, these nuclei can quickly develop into new sources of local propagules and are an important stage in the establishment process. Vigilance to detect such patches, and early action to remove them, may save the need for much more extensive clearance in the longer term.

• *Maximizing desirable forms of invasion resistant ground cover in habitats with waste or disturbed ground*
A number of habitats which are not under active management because they are unproductive (e.g. the understorey of plantations or marginal pastureland), contain bare or disturbed ground. Not only are these habitats prone to invasion, but also, the presence of the invasives may not be perceived as a problem. However, they can act as large population reservoirs, threatening further colonization elsewhere. To eliminate these, by actively encouraging a dense undercanopy of benign species, is good practice, and may prevent considerable problems to other land users. In upland areas, dense fern swards are currently proving excellent aid to this task, as they form a dense barrier which both prevents seed from landing, and shades-out emerging seedlings. They also

require little maintenance, are relatively easy to establish, and can greatly aid in conservation, as several rare native species are potentially useful.

• *Minimizing the invasibility of the road network, to suppress its role as an efficient invasion corridor*
Roads are major invasion corridors around the world. They provide a continuous, linear stretch of disturbed ground, which in the upland areas of St. Helena is often fringed by steep, bare banking, thus increasing the area of colonisable habitat available to ruderal species. Numerous aggressive colonists and short-lived weedy species find a major habitat source in these areas, facilitating their rapid spread between different parts of the island. In some cases, roads may hold the majority of the population, e.g. for toad rush *Juncus bufonius*, common mouse-ear *Cerastium fontanum* and the grass *Paspalum urvillei*, which is exceptionally common at higher altitudes. The first two of these species are of minor importance as they are unlikely to become problematic elsewhere, but the latter species could eventually become widespread on rough ground such as plantations and neglected meadows, where its tussocky growth-form could become a nuisance. Roadside weed populations rely on regular seed set to maintain viable populations, and these could be substantially reduced if the bare marginal areas were maintained in a densely-vegetated state, thus providing competition for the ruderals and removing sites for germination. A mix of pasture grasses could be effective at achieving this aim, and in the upland areas, an even more effective remedy may to vegetate bankings with native fern species (and even endemic flowering plants such as the small bellflower *Wahlenbergia angustifolia*), which already thrive well in places. Such habitats could thus potentially be converted to an invaluable conservation resource, offering much needed habitat for rare endemics, and furthermore, acting as invasion corridors for desirable rather than undesirable species.

• *Ensuring that pastures are cleaned regularly*
Even unpalatable pasture weeds will be grazed off by livestock as small seedlings, and seldom manage to establish in high-intensity grazing systems. Unfortunately from this perspective, St. Helena pasture is maintained under low intensity, and even in well maintained paddocks, corners may go ungrazed for sufficient periods to permit invasion. Conversely, overgrazing may result in excessive poaching of the ground, thus creating additional disturbed areas for colonization. Fine control of grazing regimes achieves best weed suppression, necessitating some form of stock rotation. This should be possible for large land owners, but is difficult to implement in small farming operations where the owners lack the resources, time and/or knowledge to maintain rotation, especially in the summer when the dry ground provides little suitable forage. Despite the difficulties, the cost of clearing weed infestations, both for the individual land owner and neighbouring farmers who may suffer from secondary invasions, may well prove to be greater than the cost and effort required in regular low level maintenance, even if this involves regular manual weeding.

• *Seeding pastures with invasion-resistant grass mixes*
Kikuyu grass *Pennisetum clandestinum* is the ubiquitous pasture species over most of the island, favoured due to its vigorous growth and highly competitive nature. However, monocultural grazing systems carry inherent risks. Disease could have a catastrophic effect on the farming industry, the unchanging sward imposes constant nutrient stresses on the soil and a varied diet may prove to be better for the health of the stock. One particular problem with kikuyu is that it tends to form a rather sparse, open

mat, which, when grazed-back, contains numerous gaps. The bare ground presents further opportunities for invaders to establish. In order to close such gaps, a mixed pasture, containing both kikuyu and a variety of finer hay grasses (e.g *Anthoxanthum odoratum* and *Agrostis capillaris*) may ultimate provide better invasion resistance. Such swards are technically difficult to achieve, as kikuyu can rapidly outcompete other species, but it is only likely to do so under lower grazing intensities when it can dominate. Extensive work on grassland technology in the 1970s saw a variety of new forage species trialed on St. Helena, and with a greatly increased global knowledge bank available to draw on today, it is likely that further efforts in this area could achieve productive results.

• *Maintaining effective control of introduced animal pests (e.g. mynahs, rats and mice), which may be responsible for seed dispersal of a number of invasive plant species*. Introduced mammals and birds create an additional range of problems for the island, and their control is needed for many reasons outside the scope of this discussion. In the interest of invasive plant control, such work is also vitally important. Mynahs and rats in particular feed on a variety of berries and seeds, and are undoubtedly major seed dispersers for some of the most serious invaders, including wild mango *Schinus terebinthifolius*, creeping asparagus *Asparagus densiflorus*, wild coffee *Chrysanthemoides monolifera*, guava *Psidium guajava* and red tungy *Opuntia stricta* var. *dillenii*.

Currently, the main methods of control practiced on St. Helena are largely manual, involving the uprooting, cutting or spraying of vegetation stands. These are usually the most reliable and effective approaches, and there are rarely any labour-saving short-cuts to be taken. However, as such activities are certain to be required long into the future, even reasonably large initial investments in labour-saving options may prove cost-effective in the long term. Since many sites are difficult to access and pasture is often very steep, mechanization of control procedures is often prevented by the difficulty of getting machinery to the sites, but solutions to such problems have been explored in many parts of the world.

Forms of biological control offer further options which may be explored more effectively on St. Helena. In the loosest sense, these could involve using mammalian herbivores such as goats for targeted local impacts on problem species. Goats have devastated the natural environment of the island in the past, and the risk of their escape has lead to a natural reluctance to encourage their use today. However, small numbers are still kept in certain areas, and if very carefully regulated can be very effective at weed suppression. Under certain circumstances, sheep can also be used, although they should be regarded as an equal danger to the environment if escaping. Goats in particular are useful because many breeds will preferentially browse woody species, and feed readily on even spiny shrubs such as furze. Whereas they are unlikely to completely kill the plants, they can severely clip the growth, making it much easier to access the remnants for removal. A workable scheme could see a small herd, available to be moved across the island to problematic locations and achieve relatively low-cost management, if suitable long-term shepherding could be provided. Although a venture would initially be largely experimental, the use of livestock for habitat management purposes is currently fashionable in many parts of the world.

More traditionally, biological control is taken to mean the introduction of invertebrate pest species which attack a particular host species. In general, the infestation does not remove the host, as this would also kill the biocontrol agent, but it does check the rate of growth or reproduction, and therefore reduces the population density of problematic invaders, possibly reducing their competitive advantage over other species and also making them more susceptible to other forms of management. Such measures have already met with some success with the arrival of the Lantana lacebug *Teleonemia scrupulosa*, which causes severe leaf damage to lantana, and the Cactoblastis moth *Cactoblastis cactorum*, which feeds on tungy pads (Fig. 21). Whilst biological control agents offer the promise of very widespread pest control at low cost, they also carry considerable risk, as numerous examples around the world testify (Simberloff & Stiling, 1996). An essential requirement of a good biocontrol agent is that it is extremely host-specific, and will not damage other, more desirable species. To prove host specificity requires extensive laboratory trials, and even then, there is no guarantee that behaviour will remain constant under all environmental conditions. Furthermore, insects evolve rapidly due to their short generation times and massive population sizes. When exposed to a new environment with numerous untapped food sources close at hand, the ability to switch hosts may develop at a later date (Frenzel *et al.*, 2000). Despite the potential pitfalls of biological control, it is widely regarded as a promising and often worthwhile technique, with many successes. Currently, a number of invasive plant species do not have natural predators on St. Helena, and this is an important contributory factor in conferring them with a competitive advantage over natives.

Figure 21. *Cactoblastis catorum* (Pyralidae) caterpillars feeding on *Opuntia stricta* var. *dillenii*. One of the few successful biocontrol agents introduced to combat St. Helena's invasive plant species.

Therefore, biological control can be seen as a good way of restoring the ecological balance. Some invasive species are more appropriate candidates for biological agents than others, and for those which are closely-related to native species (in the same genus, or sometimes the same family), the risk is probably too great, particularly if the target herbivore is a seed predator as these may carry a particularly high impact on reproduction. For example, introducing seed predators of whiteweed would present a risk to native gumwoods (*Commidendrum* spp.). Leaf herbivores would present less of a risk, as the ability to cope with the unique toxins in whiteweed leaves is very different from that required to overcome the gummy resins in gumwoods, but the overall level of control may be reduced.

Early warning and eradication of developing threats

Two recently established species, African fountain grass *Pennisetum setaceum* and creeping asparagus *Asparagus densiflorus*, represent a significant impending threat to St. Helena's environment. We do not yet know how damaging these will prove to be in the future, but the worst-case scenario is extremely serious, and at best, they are almost certain to incur substantial investment in control, over a prolonged time period. Already, both species are well-established and costly eradication programmes are difficult to envisage. However, if either species had been identified much earlier in the colonization process, the possibility of removing them would have been much more practical, and could have been achieved at a fraction of the management costs which are now perhaps inevitable. Similarly, rapid increases in the range or abundance of particular invasive species, even if already locally common on the island, may indicate an ecological change in their favour, and immediate awareness of such increases places land managers in a much better position to develop a mitigation strategy.

The establishment of a suitable early warning system, to identify such threats and respond to them swiftly, is a relatively basic yet valuable precaution. The three elements of such a system are:

- Trained staff, able to identify new species or changed distributions and recognize their threat.
- A suitable data recording scheme, so that the distribution of plant species across St. Helena can be monitored over the long-term and changes assessed.
- Some capacity to analyse the data and respond to the issues which arise.

There are various ways in which such a scheme could be implemented, and although it inevitably requires dedicated professional time, need not be expensive or particularly draining on manpower. As part of the SAIS project, a database of St. Helena plant distributions has already been set-up and a baseline data set assembled. It is hoped that this can be maintained into the future, and updated with new records at a low-level over the coming years to provide an ongoing picture of patterns of change. Georeferenced data of new plant records could be submitted by anyone – professional or amateur, provided there is a system for doing so. In the UK, an extremely successful scheme largely thrives on voluntary records submitted by the public and maintained by a small number of dedicated staff at the national Biological Records Centre. This is unlikely to work as efficiently on St. Helena where there are few trained and enthusiastic amateur naturalists to drive it, but publicity and encouragement, perhaps working through the St. Helena Nature Conservation Group, may be able to provide at least an element of the scheme. This, in turn, could be supplemented by periodic, structured surveying exercises (for example, undertaken once a decade by ANRD). The further, inevitable requirement is for adequate training, in database management, plant identification and the ability to interpret ecological changes.

Prevention of new introductions

Given the many hidden costs incurred when serious weed infestations develop, and the massive challenges of eradication, there are clearly huge benefits in preventing their arrival completely. It has been widely shown that biosecurity policies are extremely cost-effective. Such measures are currently enforced by the St. Helena government although the establishment of a number of new weed species over the past 25 years, including some potentially serious ecological threats, indicate that there are still some issues to be addressed. Despite this, it remains unclear exactly when, where or how such species arrived, and it seems, albeit entirely anecdotally, that the current situation may be somewhat better than it was, even in the recent past. The number of plant species brought in from elsewhere for cultivation on the island does not seem to be increasing rapidly. Rather, there seems to be a level of acceptance of this amongst the public, who are inclined to make use of material already available. This was clearly encouraged in the recent past, when attractive endemic species such as the ebony *Trochetiopsis ebenus*, were widely distributed for use as ornamentals by ANRD. Such measures represent excellent practice, as they not only promote public education of conservation issues, but also distribute propagules of threatened species across the island as potential sources of recolonization. The programme has apparently declined in the past few years, and greater impetus in the conservation nursery may be beneficial.

The three main elements of successful biosecurity policy are as follows:

- Public education of the dangers of importing foreign species. With the input of the SAIS project, the issue has been a relatively high profile over the past few years, and it is important that others continue this role after the end of 2009.
- Adequate interception facilities. Jamestown dock has for many years been the front line of the battle, and it is constantly necessary to ensure that the infrastructure for intercepting foreign material is maintained to the highest standards. With the proposed airport development, and the associated construction of docking facilities in Rupert’s Bay, two major new pathways of entry are likely to be established, thus trebling the potential for alien infiltration, and similar precautions must be maintained at these gateways.
- An appropriate legal framework to implement biosecurity. It is essential that the legal tools are effective at preventing undesirable species from entering St. Helena, and yet flexible enough not to be restrictive to personal liberties. Globally, such frameworks have been developing substantially in recent years, and particularly in the European Union, the biosecurity element has been diluted somewhat over concerns of restricting free trade. Further problems arise because from the difficulty of identifying accurately what is likely to constitute an invasive threat.

In the face of these problems, to achieve maximum effectiveness, the criteria for banned species must be updatable on a rapid and regular basis to respond to developing issues. Those experts interested primarily in achieving good biosecurity tend to favour a cautious approach, where species are subject to rigorous scrutiny until they are proven to not represent a threat. Although attempts at developing screening protocols for interception of likely risks generally have a low success rate (Daehler & Strong, 1993), a few very useful criteria have emerged from such studies (Daehler & Carino, 2000). Potentially problematic imports often have one of the following traits:
(i) they are considered invasive in a region with similar climate elsewhere
(ii) they are closely-related to an endemic species, and therefore risk potential hybridisation
(iii) they are community dominants
(iv) they have extremely fast-growth rates (often capable of spreading extensively through clonal growth) or rapid colonization ability

Increasingly, awareness of global invasive issues is shared globally on the internet, through web sites such as that of the Global Invasive Species Programme, and it is therefore becoming increasingly easy to compile and update lists of potential threats. *Restoration of degraded ecosystems*

Of equal importance to removing invasive species is ensuring that the legacy is a vibrant and functional ecosystem. Often, the presence of such well-balanced habitats contributes further to invasion-resistance, and therefore aids weed control for neighbouring land-owners, in addition to general benefits such as protection from erosion and improved water retention.

Use of natural products can provide incentives for management. As an example, Port Jackson willow *Acacia longifolia* forest currently covers large areas with poor-quality habitat. These have extremely low biodiversity, with little understorey and impaired ecosystem development. However, willow is a useful forage species, which could be utilized more frequently to supplement livestock diet during the dry summer period. This would aid pasture management by permitting more flexibility in grazing regimes, and if directed effectively, it would also help to open-up gaps in the Acacia stands, encouraging a better habitat structure, allowing the establishment of a better herb layer, and developing a more complex, functional ecosystem.

Native species, particularly endemics which are currently threatened, are of major importance in habitat restoration. Ecologically, these are guaranteed to be 'safe' to use for revegetation, and the recovery of their populations is a priority for conservation, with ultimate knock-on benefits for the ecotourism market: a potentially very promising source of future income for the island. The endemic species which have evolved on remote islands are often regarded as 'evolutionary dead-ends', which are hopelessly disadvantaged compared to the much fitter alien introductions. However, this is often far from the truth. Island endemics evolved to be perfectly adapted to the pristine environments which formerly existed on their islands, but were not able to cope with the extreme ravages which past human settlers created in their fragile landscapes. On St. Helena, species which had evolved in the absence of vertebrate grazers were defenceless against the huge herds of goats which were allowed to roam free, and succumbed to massive deforestation. Fortunately, in the modern conservation-aware society, both of these threats have greatly abated, and conditions are once again suitable for endemics to flourish. Pioneering work within Diana's Peak National Park has shown that the high altitude native cabbage tree woodland and

Figure 22. St. Helena ebony *Trochetiopsis ebenus* (and *Trocheiopsis ×benjaminii*), restored to the

wild at Ebony Plain. Invasive species are returning, but many native plants remain in good health.

tree fern thicket remains stable and very resilient. Similar experiments with some of the lowland endemics may prove that they are the perfect solutions for re-establishing vegetation across dry, eroded coastal habitats.

Much work still needs to be done to secure the long-term survival of native species. Many of the populations were reduced to such small numbers that genetic diversity is extremely low, and the viability of remainder may take centuries to recover fully. In other cases, populations remain critically small, and often too dispersed to permit adequate resilience. A minimum number and spread of individuals is required to permit widespread cross-pollination and to offer resilience against local extinctions following catastrophe at a particular site. Ultimately, a system of interconnected habitat patches is needed, encompassing suitable parts of the island and a range of native habitat types.

Particularly at low-mid altitudes, the dominance of alien shrublands is so great that it is no longer practical to consider re-establishing native habitats, but native species can still form an important part of restoration schemes (D'Antonio & Meyerson, 2002). It remains to be seen how novel mixes of species, such as the introduction of boxwood *Mellissia begonifolia*, scrubwood and gumwood (*Commidenrdum rugosum* and *C. robustum*) to open scrub of lantana or wild mango *Schinus terebinthifolius* would work, or the conditions under which the endemics could coexist best. Such experiments are well overdue. The interesting previous attempt to revegetate Ebony Plain with St. Helena ebony *Trochetiopsis ebenus* (Fig. 22) now demonstrates partial success. Although the area is now being reinvaded by lantana and red tungy, ebony forms excellent ground cover and remains locally dominant, although suffers from the severe disadvantage of self-incompatibility due to the lack of genetic diversity, which prevents it from becoming truly self-establishing.

Other native species could be used to increase diversity and supplement ecosystems with a greater range of functional roles which may now be largely lacking. The endemic hair grass *Eragrostis saxatilis*, is easily propagated and provides useful ground cover with sufficient openings to allow germination of other species. Whereas this is more suited to open areas, tussock sedge *Bulbostylis lichtensteiniana* forms an excellent sward under woodland canopy, even in very dry habitats. It is one of the few species to survive under the very species-poor environment provided by Port Jackson willow *Acacia longifolia* (Fig. 23), and could be similarly used prevent erosion, improve litter quality and create sheltered microclimates which encourage germination in a range of other species stands, perhaps proving especially valuable for the Millennium Forest gumwood restoration project. Its tiny sister species, the neglected tuft sedge *Bulbostylis neglecta*, is an early colonist of very loose, eroded soils, helping with the preliminary stages of stabilization and facilitating encroachment by other species. If this was widespread around Jamestown (as it perhaps once was), the colonization of bare, dangerous slopes may be accelerated. Even small ways of helping such processes could play a part in lessening the danger of land slips.

These few examples provide only a limited indication of the potential for ecosystem improvement. Neither is it entirely necessary to use native species. Some introductions, which clearly add value to the ecosystems they inhabit and do not have particularly invasive tendencies, may be excellent supplements to restoration. Examples include saltbush *Atriplex semibaccata*, which prevents erosion, everlasting *Helichrysum bracteatum*, which is a good source of nectar, and thorn *Erythrina caffra*, for hedging

Figure 23. Tussock sedge *Bulbostylis lichtensteiniana* forming a luxuriant sward under Port Jackson willow *Acacia longifolia* canopy.

and shelter in upland areas. Species such as Cape Yew *Podocarpus elongata* and Norfolk Island pine *Araucaria excelsa* are good at intercepting mist, creating damp microhabitats ideal for epiphytes (tree-living species) and native ground cover. Their heavily-shaded canopies are rather dark for aliens such as whiteweed and favour the establishment of ferns, providing potential to be used to create uninvasible barrier zones around sensitive areas.

Introduced species should not be overused in restoration, and native alternatives should be preferred where possible. However, experimentation should be encouraged, provided the progress of the project is adequately monitored and success evaluated to inform future plans. Scientifically replicated trials, comparing different restoration conditions, should ideally be used to determine the best approach to use, and regular data collected on canopy development, growth rates, litter formation and seedling establishment, obtained from fixed plots according to standard methodology.

Ascension Island

The potential for invasive control on Ascension is much less than that on St. Helena, partly because of the technical difficulties involved but also as a result of the greater financial and manpower constraints which currently dictate conservation strategy. Many of the same longer-term principles apply, but the following discussion focuses on those options which are most likely to be relevant in shaping short-term direction.

Control of existing problem species

The large number of highly-invasive species which are already well-established, and expanding in most cases, could now only be addressed with a massive investment. This necessitates that any management of them must often be largely reactive rather than part of a strategic programme. Current policy is to target priority sites as and where funds are available – for example, clearance of turtle nesting beaches, sites of historical or geological importance, and endemic plant habitats. Unfortunately, such measures are often particularly labour-intensive because the sites are generally surrounded by a large pool of invasive species propagules, which results in rapid reinvasion.

Given that resources permit the extermination of only a relatively small proportion of the total population of any invasive species, a focus on newly-established satellite populations may be particularly cost effective. Since these act as nuclei for the colonization of new areas, then the removal of just one plant could save the need to control hundreds a decade later. Unfortunately, assessing whether such satellites represent a genuine threat may be difficult and acts as a discouragement to action. For example, removal of the few Mexican thorn trees which have currently reached the edges of Waterside wideawake fairs could ensure that an infestation does not develop later, becoming a significant impediment within the breeding bird colonies. It is debatable whether the species could ultimately establish under these harsh conditions (i.e. in an extremely dry environment with much disturbance and heavy guano deposition), but if it does, the consequences could be damaging. Investing a few days effort into precautionary clearance appears to be an obvious option, but when the decision also involves diverting manpower from other critically important activities, and this represents just one of many desirable minor actions, all with equal merits, the reality becomes more complex.

In view of the magnitude of management issues, it seems that to achieve even a limited but effective control programme requires significant amounts of dedicated staff time. This need is pressing. With numerous species spreading at a rapid rate and the remnants of the natural, open landscape disappearing fast, the native desert areas and their concomitant native and endemic plant and animal communities now constitute an highly threatened habitat type. The spread of Mexican thorn represents the major immediate issue, but yellowboy is probably becoming a similar threat, tree tobacco, guava and Bermudan cedar substantially compound the problem and the little noticed impacts of the general greening of the lowlands by numerous other species needs careful consideration. Ideally, a system of designated open areas, with interlinked habitat refuges where invasives are at least maintained at low density, is required to preserve the landscape and provide essential habitat for invertebrates (Belton, 2008a).

A further developing problem associated with Mexican thorn is the developing fire risk which it presents. Unlike many *Acacia*-like species of arid areas, Mexican thorn retains foliage all year, and does not shed large quantities of foliage during the driest seasons which are particularly incendiary. Nevertheless, this still leaves a large volume of combustible wood, and as the populations mature further, the quantity of dead trees and fallen branches may increase. A professional evaluation is probably necessary, and preventative measures may be required, such as the creation of fire breaks, and increased public awareness of the dangers.

Another important aspect of invasive plant control is the management of herbivores and seed dispersers. At least one major scheme with this aim has been suggested in the past, involving an enclosed donkey area (Pickup, 1999). Donkeys probably disperse Mexican thorn seed to new locations, and this measure is aimed at restricting the spread. But the idea has other benefits. The donkey population is currently in decline, and provided that adequate food and water is ensured, the measure may prove critical to their welfare by preventing them from straying into high-risk areas. The fence may equally help to exclude sheep, which may be similarly important at dispersing Mexican thorn seed, and encourage the donkeys to graze sapling trees more extensively, thus suppressing new growth.

Currently a more major biological issue is the potentially expanding rat population. Since rats both feed on, and disperse the seed of invasive species, the control of both invasive plants and mammals is linked closely. Rats not only feed on guava, but they occasionally pith twigs of Mexican thorn in the lowlands and take their seed. It is not known whether the seeds are destroyed in this process, so a dispersal role has yet to be demonstrated. However, many other species are probably successfully dispersed, including blackberry and raspberry, two favoured food sources at higher altitudes. An assessment of the rat population is urgently needed, and more resources may be required if the already extensive control is insufficient to prevent further increases.

Invertebrate biological control (intentional or inadventent) has been attempted on Ascension for at least two invasive plant species. Lantana lace bug is widespread and is perhaps an important factor in the much lower abundance of lantana on Ascension compared to St. Helena. Plants are very thinly scattered across the dryland areas, but these are often heavily defoliated and covered in powdery smuts. Herbivore and pathogen attack on lantana is apparently less effective in upland areas, presumably because growth is sufficiently vigorous to overcome the damage. Three species of cowpea weevils (Bruchidae) were released to control Mexican thorn in the 1990s (Fowler, 1997), and these have apparently been supplemented by further specialist sap-feeding bugs, introduced accidentally. A review of the performance of these species is currently under way (by Liza White, 2009). It seems that at least two of the Bruchids are still widespread, and the bugs are perhaps now responsible for locally-intensive bursts of defoliation (Fig. 24). Whilst the release of biological control agents is reasonably time-consuming and the results variable, it may be a good option to explore for additional cases on Ascension. Maintenance costs are minimal once the agents have established, thus achieving a level of control with little drain on manpower or resources. Also, the very small native flora ensures that many specialist herbivores could be released with little danger of switching host to protected species.

Figure 24. Defoliation and aberrant growth on a twig of Mexican thorn *Prosopis juliflora*, apparently associated with high levels of infestation by sap-sucking bugs. These symptoms are widespread, and may cause substantial impairment.

Early warning and eradication of developing threats

The limited resources available on Ascension make it especially cost-effective to identify and eradicate new introductions before they can become established. This strategy requires sufficient knowledge and vigilance to recognise and evaluate potential risks at an early stage. It is therefore essential to maintain a well-trained staff base, and to ensure that routine activities permit observation over a large part of the island. New records should be logged on the AEIOU GIS system, and both islanders and visitors encouraged to submit information, or to bring unidentified specimens to the Conservation Office for examination.

During the course of the recent survey, a small number of emerging invasive threats were recorded which are excellent candidates for such eradication measures, and could potentially be removed at low cost if prompt action is taken. Whilst Belton (2008b) deals with some of the issues, supplementary notes are provided as follows:

(i) Wild mango *Schinus terebinthifolius*
A few plants are present on the ascent to Sister's Peak, and a small but dense patch in the gully between the Mountain Road and the south side of Middleton's Ridge. As this species is extremely invasive on St. Helena, and could potentially be well-adapted to the upper dryland areas of Ascension, its immediate removal is strongly recommended.

(ii) Bull grass *Juncus capillaceus*
A major invasive pasture weed on St. Helena. Since only approximately 4 (certainly less than 10) tussocks are present, all on Elliott's Path, removal could again be effected very easily. However, the identification has not yet been verified as no flowering shoots were present during the trip.

(iii) Purple nut sedge *Cyperus rotundus*
This species is a widespread and very persistent tropical weed of disturbed and agricultural land (Fig. 25a). It is already common in a number of flower beds in Georgetown, in a few sites on the U.S. Base, and in flowerbeds around Garden Cottage. Removal is difficult, because the plant produces deep rhizomes and numerous tubers from which it can regenerate. However, eradication is still very feasible with a coordinated effort, and could prevent much greater longer-term costs.

(iv) Jerusalem thorn *Parkinsonia aculeata*
This is an attractive shrub or small tree which is popular as an ornamental in Two Boats and Georgetown thanks to its drought-resistance and bright yellow flowers (Fig. 25b). At present, it has not established in the wild, but adventive plants were found in two places across Donkey Plain, and it successfully self-seeds near cultivated populations. The likelihood of this species developing into a problem is uncertain, but it has become invasive elsewhere in the world in areas where Mexican thorn has already established (Pasiecznik *et al.*, 2001). *Parkinsonia* establishes a secondary wave of colonization after a few decades, when the mature *Prosopis* stand becomes fragmented by the die-back of ageing trees and the soil has been modified by persistent deposition of leaf litter. It can thus compound the problems already inflicted by its predecessor. The eradication of ornamental species, often in private ownership, may be unpopular, and the need is to do so is often not perceived. A successful initiative must involve public education of the risks, and less harmful alternative garden plants should be cultivated and offered in replacement for any trees removed.

Figure 25. Two potentially aggressive alien colonists which could be considered for eradication: (a) Purple nut sedge *Cyperus rotundus*, (b) Jerusalem thorn *Parkinsonia aculeata*.

(v) Kikuyu grass *Pennisetum clandestinum*

Kikuyu is currently used as a lawn grass, so its immediate eradication may be unpopular and unnecessary. It is known from at least one Garden in Georgetown, from the picnic area at the Red Lion, and from a cropped grassy sward near the old Marine Barracks. Elsewhere, this is a highly aggressive species which can creep through other dense vegetation and out-compete low herb swards. The ecological implications of its establishment in the wild on Ascension are unknown, but there is a reasonable risk that it may exacerbate existing problems. Therefore, careful monitoring of future escapes is recommended, with action to be revised if the status changes.

(vi) *Euphorbia* sp. (aff. *E. repens*)

As mentioned previously, a new, and as yet unidentified *Euphorbia* species has recently appeared on the U.S. Base. Although only adventive and likely to remain a minor weed, the establishment of species closely-related to threatened endemics is highly undesirable, due to the risk of hybridisation (in this case with Ascension Island spurge *E. origaniodes*). The population is currently very localized and could therefore be eradicated easily at present.

Prevention of new introductions

Interception of newly-arrived plants or propagules is an equally cost-effective means of suppressing further waves of invasion. This presents more of a challenge than it currently does on St. Helena because there airport is already in place, and ships regularly arrive from St. Helena, the U.K., and U.S.A., with others occasionally docking from elsewhere. Furthermore, the air and sea entry points are controlled by different bodies. Facilities and procedures for inspecting goods are less well-developed than on St. Helena, as is the interception protocol. In mitigation of these factors, it may be relatively rare that islanders attempt to import live plant material.

The large number of new plant species recorded in the wild during the 2008 survey gives cause for some concern. As documented evidence of species distributions has always been very sparse, it is difficult to assess whether all of these species are indeed

Figure 26. *Sageretia subcaudata*, a shrub forming dense thickets on Green Mountain, but possibly a fairly recent introduction.

as recent as they appear, or if at least some have been overlooked for some time. A number may be a legacy of earlier days when introductions were still actively encouraged, but it seems likely that many are genuinely new colonists. These are a mix of horticultural species and are small weeds which were probably brought into Ascension as small fragments or seed contaminants of other goods. It may be easier to intercept some of the horticultural imports, and to discourage their arrival by increased public awareness measures, but it may also be valuable to focus phytosanitary measures on ensuring that imports are clean.

Of the newly-recorded list, both categories of species include examples which have already become well-established, several being particularly notable for their evident impact on the present ecology of the island, or their potential for future colonisation. The ornamental species include a *Coleus* species (possibly *C. ambionicus*), which although popular and resilient in gardens are renowned for their aggressive tendencies. The closely-related genus *Plectranthus*, which is ecologically similar, is regarded in its entirety as an invasive threat in New Zealand (pers. comm., T. Belton, 2008). Mother-of-thousands *Kalanchoe daigremontanum* is potentially well-adapted to the dry habitats of the island, and at higher altitudes, kikuyu, giant sword-fern *Nephrolepis biserrata* and the shrub *Sageretia subcaudata* (Fig. 26) are aggressive, patch-forming species already well-established on Green Mountain. Of the weeds, the grass *Enteropogon mollis* is now very common over the western lowlands, whereas Skeletonweed *Chondrilla juncea* appears to be well-adapted to colonize the bare scoria slopes of the craters and appears to be spreading quickly (Fig. 27). The issues posed by alien *Euphorbia* species, purple nut sedge and bullgrass have already been discussed.

Figure 27. Skeletonweed *Chondrilla juncea*, apparently spreading rapidly across the barren scoria slopes of Sister's Peak and Cross Hill.

Restoration of degraded ecosystems

This final element of the management programme is perhaps the most challenging of all on Ascension. Realistically, short-term goals may be restricted to rescuing the endemic plant species on Green Mountain, which will require much effort over many years to achieve. However, the project in itself is likely to provide substantial insights into more general ecosystem restoration and the management of aggressive weed populations across the island.

Figure 28. Left: Trial restoration area on Green Mountain, where endemic species such as the fern *Pteris adscensionis* are currently being re-established. Right: Conservation officer Stedson Stroud with the wood chipper.

The Conservation Department have already made excellent progress in creating an initial restoration area below the bamboo forest on Green Mountain, and in developing the techniques for propagating each of the threatened endemic species (Fig. 28). During the early phase, valuable lessons have been learned in habitat maintenance (pers. comm., S. Stroud, 2008). The clearing of thick, alien scrub is extremely labour-intensive, and the recolonization of invasive seedlings is extremely rapid in the warm, humid environment. Species such as blueweed, raspberry and tallow vine *Commelina diffusa* reappear very rapidly and ongoing weeding is necessary to prevent these from smothering the endemic fern species. Even populations of *Xiphopteris ascensionense* on the branches of surrounding trees are threatened by vigorous competition from *Begonia hirtella*. A wood-chip mulch, made from the cleared invasive brashings, proves very effective at suppressing the re-emergence of ground weeds, thus enabling the endemic sward to establish. It is hoped that once a mature cover has established, then this may be effective at inhibiting further alien colonization on its own.

Thus far, the successes of the project are encouraging. Recreating the original carpet of ferns in its original form is unlikely to be realistic, but the interesting initial findings suggest that even the rarest endemics are capable of adapting to new ecological roles. Whereas *Pteris adscensionis* grows as a chasmophyte (cliff dweller) in all its known extant locations, it appears to be able to form a excellent sward on open ground. *Marattia purparascens*, which occurs on open hillside in its most natural remaining localities, seems to thrive under fairly dark forest canopy, and will even occasionally grow epiphytically on branches.

Ultimately however, much more work is needed. It remains to be seen how stable the endemic populations are over a long time period and whether they maintain resistance to reinvasion. A long-term dependence on mulching is unsustainable, and probably undesirable as this removes bare ground for germination and creates an artificially nutrient-rich soil. Furthermore, a network of at least five habitat patches is required across the Mountain to ensure the survival of the re-established habitats. Such a precaution is necessary to protect against local catastrophic events such as land-slips, disease or weed infestation. The designated areas must also develop mixed vegetation communities, comprising several native fern species, each integrated into appropriate microhabitats within the overall scheme. Practically, it may be impossible to exclude all non-natives, although some alien additions may be permissible if they integrate well with the community and help to prevent the establishment of more aggressive invaders. In particular, it may be necessary to clear a buffer zone around the restored habitats by removing the most vigorous threats. A useful tool in this process may involve the creation of barriers, comprising stands of non-invasive aliens, around the habitat in order to block the immigration of unwanted propagules. Species such as Cape yew *Podocarpus elongata* and *Ficus microcarpa* could prove useful in such attempts. Even relatively aggressive clonal aliens which could be maintained as a hedge (e.g. shell ginger *Alpinia zerumbet*) may be worth considering in limited circumstances.

Success of this project may provide extremely useful lessons in how to establish more desirable, invasion resistant habitats across lower-altitude areas of the mountain. This is a long-term goal, but one which may ultimately be necessary to maintain the stability and health of the island’s natural biome. Addressing some of the habitat management issues in the lowlands is more difficult, as it is less obvious how to proceed, and the value of doing so has more immediate benefits. Establishing a balance which provides some “natural” control over the spread of Mexican thorn, yellow boy and other invasive species which remain poorly-integrated into the ecosystem structure, would reduce the need for intervention substantially. This remains a challenge for the future, and may only be achievable with a significant increase in land use, based on creative and economically-worthwhile land management schemes.

Acknowledgements

A large number of people contributed substantially to the project during the course of the survey, both in terms of ideas and valuable assistance. Thanks greatly to the survey team, which for a large part comprised Phil Lambdon, Andrew Darlow and Tom Belton, but was supplemented by numerous capable volunteers: Fiona Burns, Rebecca Cairns-Wicks, Colin Clubbe, Pat Joshua, Susannah Musick, Steve Plato, Kath Squires, Clare Stringer, Stedson Stroud, Delyth Williams and Danielle Yon. Invaluable additional support (both practical and moral) was provided by the St. Helena National Trust, the St. Helena Nature Conservation Group and the Ascension Island Conservation Department. U.K. research, backup and administration was provided by the R.S.P.B. (especially Clare Miller, Sarah Sanders and Stella ???) and the Royal Botanic Gardens, Kew (especially Colin Clubbe, Marcella Corcoran, Martin Hamilton, Stuart Robbins, Tom Cope, Dave Simpson and the UKOTs volunteer group). Additional thanks go Alan Gray, Pat Joshua, Tara Pelembe, Clare Stringer and Stedson Stroud for additional support and advice, to the project steering groups for support and useful suggestions, and to Gary Walters for facilitating our media campaign. The South Atlantic Invasive Species Project was funded by the European Union (Project N° 9 PTO REG 5/1 PTR 003/05/EDF IX).

Appendix 1: Data definitions

(A) the DAFOR scale used to assess abundance within a 1km grid cell[1]

Category	Title	Description
D	Dominant	Dominant (or co-dominant) over a reasonably large part of the grid cell
A	Abundant	Sub- or only very locally dominant, but present in large numbers
F	Frequent	A common species in the cell, occurring regularly but in smaller numbers than above
O	Occasional	Scarce but occurring regularly throughout the cell, or fairly common over a very restricted area
R	Rare	Very thinly scattered across the cell, or very locally distributed in a few patches
V	Very rare	A few plants only
C	Cultivated	Present in the cell only as a cultivated plant

[1]Note that this scale is reflects the density of plants present, although the numbers are usually too many to count and depend on the size of the plant – obviously a large tree requires many fewer individuals to become the dominant species than a tiny annual species. As an approximate rule of thumb, the number of plants present could be estimated according to the following expression:

$\mathrm{Log}_{10}(N_{max}) = \mathrm{Cat}/\mathrm{Diam}^{0.45}$

Where N_{max} is the maximum number of species in the category, Cat is the category rank (V=1 to D = 6) and Diam is the mean diameter of the plant canopy in metres. Where the grid cells were smaller because they were subdivided on Green Mountain or contained sea, then these totals should be scaled down according to the reduction in the area available.

(B) the DAFOR scale used to assess abundance within a point quadrat[1]

Category	Title	% ground cover
D	Dominant	≥ 60
A	Abundant	≥ 30
F	Frequent	≥ 15
O	Occasional	≥ 5
R	Rare	≥ 1
V	Very rare	A few plants only
C	Cultivated	Present in the quadrat only as a cultivated plant

[1]Note that in contrast to the DAFOR scale used within 1km grid cells, this scale is reflects the local % cover of the species.

(C) Categories used to indicate the frequency of cultivation of a species

Category	Description
3	Very commonly planted within the cell, most likely either as a forestry or crop species
2	Planted in a number of locations within the cell
1	A few plants or small patches present, most likely in gardens
0	Not cultivated

(D) Habitat classification, based on IUCN categories[1]

Habitat_name	IUCN category	Subcategory	Description
Forest			
Casaurina forest	**1.5** Subtropical/Tropical Dry Forest	1	Forest dominated by *Casuarina equisetifolia*
Gumwood woodland	**1.6** Subtropical/Tropical Moist Lowland Forest	1	Forest dominated by native *Commidendrum robustum*
Dry alien thicket		2	Sclerophyllous or deciduous thickets of alien trees (e.g. *Schinus terebinthifolius* /*Erythrina caffra*)
Tree-fern thicket	**1.9** Subtropical/Tropical Moist Montane Forest	1	High altitude vegetation dominated by *Dicksonia arborescens*
Alien tropical moist forest		2	Moist tropical forests of alien trees
Shrubland			
Succulent scrub	**3.5** Subtropical/Tropical Dry Shrubland	1	Arid scrub dominated by succulents, esp. Cactaceae or Agavaceae
Thorn scrub		2	Arid scrub dominated by *Prosopis juliflora* or thorny *Acacia* sp.
Scrubwood scrub		3	Native arid scrub dominated by *Commidendron rugosum*
Creeper waste		4	Barren arid areas dominated by *Carpobrotus edulis* and *Atriplex semibaccata*
Fern swards	**3.6** Subtropical/Tropical Moist Shrubland	1	Dense stands of fern (any species except *Dicksonia arborescens*)
Lantana scrub	**3.8** Mediterranean-type Shrubby Vegetation	1	Arid areas dominated by *Lantana camara*
Chrysanthemoides-Diospyros scrub		2	Arid areas dominated by *Chrysanthemoides monolifera* and/or *Diospyros pallens*
Juniperus scrub		3	Semi-arid areas dominated by *Juniperus bermudiana*
Sclerophyllous shrub/woodland		4	Shubland or forests dominated by sclerophyllous woody species (e.g. *Olea europaea* ssp. *africana*, *Pittosporum viridiflorum*, *Schinus terebinthifolius*)
Leucaena forest/scrub		5	Upland shubland or forests dominated by leguminous trees, mainly *Leucaena leucocephala*
Tecoma shrubland		6	Shrubland dominated by *Tecoma stans*
Grassland			
Semi-natural grassland	**4.4** Temperate grassland	1	Unmanaged grasslands
Tussock grassland	**4.5** Subtropical/Tropical Dry Lowland Grassland	1	Tussocky grasslands e.g. dominated by *Pennisetum setaceum*
Wetland			
Waterfall	**5.1** Permanent Rivers/Streams/Creeks	1	Waterfalls
Permenant stream		2	Limnic zone of watercourses flowing permenantly or for most of the year
Riparian margins		3	Littoral zone of (semi-)permenant watercourses
Dry gully	**5.2** Seasonal/Intermittent/Irregular Rivers/Streams/Creeks	1	Watercourses running dry for most of the year and any margins influenced by water seepage
Seepage areas		2	Slopes damp or dripping with water
Riparian Schinus scrub	**5.3** Shrub Dominated Wetlands	1	Dense stands of *Schinus terebinthifolius* along watercourses
Riparian scrub (other)		2	Other scrub along watercourses

Habitat_name	IUCN category	Subcategory	Description
Marshy areas	**5.7** Permanent Freshwater Marshes/Pools	1	Areas subject to regular indundation, forming (temporary) marsh patches
Rocky areas			
Inland cliffs	**6.1** Cliffs	1	Inland cliffs
Rocky areas	**6.2** Rocky areas	1.1	Exposed rock or bare rocky ground other than on cliff faces or lava fields
Caves and crevices		1.2	Caves and crevices
Lava fields		1.3	Barren areas covered with lava flows or blocks
Scree	**6.3** Scree	1	Scree
Sparsely vegetated hillside	**6.4** Barren fine rocky areas	1.1	Barren hillsides with some soil and not dominated by recognized community types
Stony heath		1.2	Barren, level stony ground with some soil
Erosion slopes		1.3	Barren slopes with loose substrate smaller than scree
Desert			
Semi-desert	**8.1** Hot Desert	1	Semi-barren areas dominated by *Hydrodea cryptantha*/*Mesembryanthemum crystallinum*/*Suaeda fruticosa*
Coastal desert		2	Barren hot, dry areas subject to salt spray
Volcanic desert		3	Barren hot, dry areas predominantly covered by fine substrate
Clinker field		4	Barren hot, dry areas predominantly covered by fine clinker
Sand deposits		2	Areas of pure sand
Marine intertidal			
Rocky shore	**12.1** Rocky Shoreline	1.1	Rocky coastal margins (general)
Coastal lava fields		1.2	Lava fields subject to coastal sea spray
Sandy Shoreline	**12.2** Sandy Shoreline	1	Sandy beaches
Shingle shore	**12.3** Shingle and/or pebble Shoreline and/or Beaches	1	Shingle or gravel beaches
Marine Coastal/Supratidal			
Sea cliffs	**13.1** Sea Cliffs and Rocky Offshore Islands	1	Coastal cliffs
Seabird colonies		2	Coastal areas heavily influenced by guano
Artificial			
Cultivated land	**14.1** Arable Land	1	All forms of cultivated land
Mid-level pasture	**14.2** Pastureland	1	Seasonally-dry or poor pasture: mainly at mid-altitudes
Upland pasture		2	Productive grazed pasture: mainly at higher altitudes
Restoration areas	**14.3** Plantations	1	Areas recently planted with native species
Fruit orchards		2.1	Fruit orchards
Banana groves		2.2	Banana groves
Podocarpus woodland		3	*Podocarpus* woodland including where naturally regenerant

Habitat_name	IUCN category	Subcategory	Description
Eucalyptus woodland		4	*Eucalyptus* woodland including where naturally regenerant
Pinus/other conifer woodland		5	Conifer plantations (e.g. Araucaria/Pinus)
Lowland Acacia forest/scrub		6	Dry low-mid level areas planted or colonized extensively with non-thorny *Acacia* (e.g. *A. longifolia*)
Flax plantations		7	Plantations of *Phormium tenax*
Broadleaf plantations (other)		8	Plantations of broadleaf species not included elsewhere (e.g. upland *Acacia melanoxylon*)
Clearfells		9	Areas formerly planted with trees but recently cleared
Gardens and parks	**14.4** Rural Gardens	1	Gardens and parks
Urban areas	**14.5** Urban Areas	1	Urban areas and buildings with extensive concrete standing
Farmsteads		2	Farms and other low density buildings
Derelict buildings		3	Derelict buildings which have been partially colonized by vegetation
Ruderal		4	Disturbed waste ground
Walls		5	Free-standing walls
Tarmac		6	Tarmac
Tracks		7	Unsurfaced tracks
Vegetated roadsides		8.1	Roadsides and roadside banks with a cover of herbaceous vegetation
Banks along roads and paths		8.2	Bare or sparsely-vegetated banks along roads or paths
Ruderal roadsides		9	Roadsides with sparse vegetation
Organic refuse		1	Organic refuse (e.g. compost heaps and manure piles)
Non-organic refuse		2	Non-organic refuse (e.g. scrap metal, plastic waste)
Artificial/Aquatic			
Reservoirs	**15.2** Ponds (below 8 ha.)	1	Artificial water bodies
Excavations	**15.5** Excavations (open)	1	Quarries and construction sites
Sewage farms	**15.6** Wastewater Treatment Areas	1	Sewage farms and rubbish dumps
Ditches	**15.9** Canals and Drainage Channels/Ditches	1.1	Artificial ditches used at least intermittently as water conduits
Water storage areas		1.2	Artificial pools or small reservoirs used to collect rain water.
Introduced vegetation			
Tall grass/bamboo stands	**16.1** Tall grass/bamboo stands	1	Tall stands of grass/Arundo/bamboo
Tall semi-woody alien stands	**16.2** Introduced shrubby vegetation	1.1	Tall stands of vigorous semi-woody alien species e.g *Austroeupatorium inulaefolium*/*Solanum mauritanianum*/*Cestrum laevigatum*
Tall clonal alien herb stands		1.2	Tall stands of vigorous clonal alien herb species e.g *Hedychium coronarium*/*Alpinia zerumbet*
Low alien shrub stands		1.2	Monocultures of low shrubby alien vegetation e.g. *Spermacoce verticillata*

Habitat_name	IUCN category	Subcategory	Description
Furze scrub		2	Dense stands of *Ulex europaeus*
Neglected tall alien herb areas	**16.3** Introduced herbaceous vegetation	1	Overgrown grassy or herb-rich patches of alien species
Hedges	**16.4** Introduced trees	1.2	Hedges

[1]Note that not all categories were present on both islands.

(E) Species status categories

(i) Native status	
Endemic	Endemic to St. Helena or Ascension
Native	Native to St. Helena or Ascension
Probably native	Status unclear, but likely to be native to either island
Possibly native	Status unclear, with a small chance that it is native
Introduced	Introduced by man to St. Helena or Ascension

(ii) Current status[1]	
Invasive	Extremely abundant in the wild and creating an economic or ecological threat (Introduced species only)
Naturalized	Well established in the wild (Introduced species only)
Forestry species	Widely planted in large numbers in wild situations and possibly self-sustaining (Introduced species only)
Adventive	Present in wild situations but not clearly established in self-sustaining populations (Introduced species only)
Cultivated only	Only present in cultivation
Extinct	No longer present in the wild or cultivation

[1]Note that many of the categories only apply to introduced species: it is implicit that native species are already established.

(F) Physical characteristics recorded for each quadrat in the community level analysis

Characteristic	Definition
Date	The survey date
Slope angle	° of slope from the horizontal. If in a ravine, taken to be the angle of the streambed.
aspect	Aspect of slope to the nearest 45° point of the compass (e.g. N, NE, E etc.)
Altitude	Elevation above sea level
Cover of bare ground	% cover of unvegetated ground (including rock)
rock	% cover of rock (particles the size of scree or larger)
bryophytes	% ground cover of mosses and liverworts
lichens	% ground cover of shrubby or foliose lichens
Canopy cover	% of sky obscured by tree layer[1]
height	Mean height of tree layer (m)
Shrub layer cover	% of sky obscured by shrub layer[2]
height	Mean height of shrub layer (m)
Herb layer cover	% ground cover of herb layer
height	Mean height of herb layer (m)
Litter cover: Dry	% ground cover of dry or sclerophyllous leaves, twigs or other litter
Moderate	% ground cover of moderately well-decayed litter
Humus	% ground cover of well decayed, humus-like litter
Soil disturbance	A score to indicate the level of soil disturbance[3]
Burning	A score to indicate the degree to which the area had been affected by fire[3]
Cutting	A score to indicate the level of brush/tree-felling, mowing or similar management[3]
Browsing	A score to indicate the level of vertebrate of invertebrate grazing on the vegetation[3]

[1]A tree was taken to be a woody plant with the canopy leaving at least 1 metre clearance for an understorey.
[2]A shrub was taken to be a woody plant with the canopy leaving no understorey clearance, or less than 1 metre.
[3] Scored as none, low, moderate or high.

(G) Population data recorded for the target species in the community level assessments

Characteristic		Definition
Estimated no. of summer-hardened individuals in quadrat		The number of plants > 1 year old, given as a range between upper and lower confidence limits
Stand height:	Maximum	The maximum height of the species in the quadrat
	Mean	The mean stand height within the quadrat
% cover		The % ground or canopy cover
Clonality		A score to assess the level of vegetative spread[1]
Plant health[2]:	% Poor	In very poor condition, likely to die
	% Impaired	Displaying obvious signs of illness or other significant impairment not caused by herbivory
	% Grazed	Suffering heavy herbivory, clearly affecting their growth of reproductive success
	% Stunted	Abnormally small (e.g. wind clipped) but not apparently suffering other impairment
	% Normal	Displaying normal growth
	% Vigorous	Displaying particularly large size or vigorous growth
Reproduction[2,3]:	% None	Not reproducing
	% Light flowering	With only a few flowers
	% Moderate flowering	Flowering moderately well
	% Heavy flowering	Approaching the maximum abundance of flowers
	% Light fruiting	With only a few fruits
	% Moderate fruiting	Fruiting moderately well
	% Heavy fruiting	Approaching the maximum abundance of fruits
Estimated no. of recruits in quadrat[4]		The number of seedlings under 1 year old, given as a range between upper and lower confidence limits.

[1]Score given as none, weak, moderate or strong.
[2]Given as the % of mature individuals present in each category
3This is intended to be a measure of maximum reproductive potential. If a plant displayed both flowers and fruits then precedence was given to the stage which is most prevalent; if both stages were equally abundant then precedence was given to fruiting, as this is closer to realizing reproductive success.
[4]Note that according to the definitions given, all annuals appear as recruits and not as summer-hardened individuals. However, they may be included within the Plant Health and Reproduction totals if present as mature plants.

Appendix 2: Glossary

Adventive species An alien species which is present in wild or semi-wild situations, but does not yet form truly self-sustaining populations and may become extinct in the short to medium term.

Aff. Affinity, closely related-to.

Alien species A species which is not native to the given territory.

Biome A complex of ecosystems which characterize a given region.

Colonist species A species currently establishing in new areas. Colonists may be alien or native.

Community A characteristic association of species which interact with each other within a given habitat.

Dominant species A species which forms the most abundant element within a community (either numerically or in terms of biomass). It's presence usually has a large effect on the physical environment and therefore on the species which can establish alongside it.

Ecosystem A complex of communities which interact with each other in a self-sustaining unit.

Endemic species A native species which does not occur in the wild outside the territory. Usually, endemics evolve within the territory from early, more widespread colonists, although occasionally, they may have colonized in their present form before becoming extinct elsewhere in the former range.

Introduced species A species which is not native and has been brought into the territory from elsewhere (more or less synonymous with "alien species").

Invasive species An introduced species which is spreading or has spread widely across the territory, and has a substantial impact on the existing ecology.

Native species A species which arrived naturally in the territory, without the aid of man.

Naturalized species An alien species which has established in the wild, and forms self-sustaining populations.

Population An aggregation of individuals of the same species. Depending on context, populations may refer to a given local area, the entire territory or to the entire global compliment.

Ssp., Subsp. Subspecies.

Var. Variety, a characteristic and genetically distinct form of a species which is not sufficiently different from other forms to be considered a subspecies.

References

Ashmole, P. & Ashmole, M. (2000) *St. Helena and Ascension Island: A natural history* Anthony Nelson, Oswestry, Shropshire.

Beatson, A. (1816). Appendix I: An alphabetical list of plants seen by Dr. Roxburgh growing on the island of St. Helena. *Tracts Relative to the Island of St. Helena*. W. Bulmer & Co., London.

Belton, T.H.M. (2008a). Invasive weed management plan for Ascension Island - 5 year plan: 2009-2014. Royal Society for the Protection of Birds, Sandy, Bedfordshire.

Belton, T.H.M. (2008b). Invasive weed management plan for St. Helena Island - 5 year plan: 2009-2014. Royal Society for the Protection of Birds, Sandy, Bedfordshire.

Belton, T.H.M. (2008c). Management strategy for Mexican thorn (Prosopis juliflora) on Ascension Island. An assessment of this species, and recommendations for management. Royal Society for the Protection of Birds, Sandy, Bedfordshire.

Brown, L.C. (1982) *The flora and fauna of St. Helena* Land Resources Development Centre, Surbiton, Surrey.

Callaway, R.M. & Aschehoug, E.T. (2000) Invasive plants versus their new and old neighbors: A mechanism for exotic invasion. *Science*, **290**, 521-523.

Cronk, Q.B.C. (1980) Extinction and survival in the endemic vascular flora of Ascension Island. *Biological Conservation*, **17**, 207-219.

Cronk, Q.B.C. (1984) W.J. Burchell and the botany of St. Helena. *Archives of Natural History*, **15**, 45-60.

Cronk, Q.B.C. (1989) The past and present vegetation of St. Helena. *Journal of Biogeography*, **16**, 47-64.

Cronk, Q.B.C. (2000) *The endemic flora of St. Helena* Anthony Nelson, Oswestry, Shropshire.

D'Antonio, C.M. & Meyerson, L.A. (2002) Exotic plant species as problems and solutions in ecological restoration: A synthesis. *Restoration Ecology*, **10**, 703-713.

Daehler, C.C. & Carino, D.A. (2000) Predicting invasive plants: prospects for a general screening system based on current regional models. *Biological Invasions*, **2**, 93-102.

Daehler, C.C. & Strong, D.R. (1993) Prediction and biological invasions. *Trends in Ecology & Evolution*, **8**, 380-380.

Dauer, J.T., Mortensen, D.A., & Vangessel, M.J. (2006) Temporal and spatial dynamics of long-distance *Conyza canadensis* seed dispersal. *Journal of Applied Ecology*, **44**, 105-114.

Duffey, E. (1964) The terrestrial ecology of Ascension Island. *Journal of Applied Ecology*, **1**, 219-251.

Ehrenfeld, J.G. (2003) Effects of exotic plant ivasions on soil nutrient cycling processes. *Ecosystems*, **6**, 503-523.

Fairhurst, W. (2004) *Flowering plants of Ascension Island* Higham Press, Alfreton, Derbyshire.

Fowler, S.V. (1997). Interim report on a visit to Ascension Island, 13-21 May 1997. International Institute of Biological Control. Report to the Administrator's Office, Ascension Island.

Frenzel, M., Brändle, M., & Brandl, R. (2000). The colonization of alien plants by native phytophagous insects. *Proceedings of IAVS symposium, 2000*, pp. 223-225. Opulus Press, Uppsala, Sweden.

Gray, A., Gardner, S., Kirk, L., Robinson, P., Smolka, Z., & Webster, L. (1998). The status and distribution of the endemic vascular flora of Ascension Island. University of Edinburgh undergraduate report.

Gray, A., Robinson, P., & Stroud, S. (2009) Use of the biological flora framework in the United Kingdom Overseas Territories: *Euphorbia origanoides*. *Biological Conservation*, **Currently on-line only**.

Hart-Davis, D. (1972). New flora and fauna. *Ascension. The story of a South Atlantic Island*. Constable & Co. ltd., London.

Hobohm, C. (2003) Characterization and ranking of biodiversity hotspots: centres of species richness and endemism. *Biodiversity and Conservation*, **12**, 279-287.

I.U.C.N. (2008) The IUCN red list of threatened species. Habitat classification scheme (Ver. 3.0). Available on-line at http://www.iucnredlist.org/static/major_habitats. Accessed Sept 2008.

Lyons, K.G. & Schwartz, M.W. (2001) Rare species loss alters ecosystem function - invasion resistance. *2001*, **4**, 358-365.

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M., & Bazzaz, F.A. (2000) Biotic invasions: Causes, epidemiology, global consequences, and control. *Ecological Applications*, **10**, 689-710.

Melliss, J.C. (1875) *St. Helena: A physical, historical and topographical description of the island, including its geology, fauna, flora and meteorology*. L. Reeve & co., London.

Oldfield, S. (1999) *Biodiversity in the U.K. Overseas Territories* JNCC, Peterborough, U.K.

Packer, J.E. (2002) *A concise guide to Ascension Island, South Atlantic* Ascension Heritage Society, Georgetown.

Pasiecznik, N.M., Felker, P., Harris, P.J.C., Harsh, L.N., Cruz, G., Tewari, J.C., Cadoret, K., & Maldonado, L.J. (2001) *The Prosopis juliflora - P. pallida complex: A monograph* HDRA, Coventry.

Pickup, A.R. (1999). Ascension Island management plan. Royal Society for the Protection of Birds, Sandy, Bedfordshire.

Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'Connell, C., Wong, E., Russel, L., Zern, J., Aquino, T., & Tsomondo, T. (2001) Economic and environmental threats of alien plant, animal, and microbe invasions. *Agriculture Ecosystems & Environment*, **84**, 1-20.

Pimentel, D., Zuniga, R., & Morrison, D. (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics*, **52**, 273-288.

Preston, C.D., Pearman, D.A., & Dines, T.D. (2002) *New Atlas of the British Flora* Oxford University Press, Oxford.

Royal Botanic Gardens Kew (1993a). Report on sustainable environment and development strategy and action plan for St. Helena. Volume 3: Status of the endemic flora and preliminary recovery programmes. Royal Botanic Gardens, Kew in association with the International Institute for Environment and Development.

Royal Botanic Gardens Kew (1993b). Report on sustainable environment and development strategy and action plan for St. Helena: Executive summary. Royal Botanic Gardens, Kew in association with International Institute for Environment and Development.

Sanders, S. (2006) *Important bird areas in the United Kingdom Overseas Territories. Priority sites for conservation* Royal Society for the Protection of Birds, Sandy, Bedfordshire.

Simberloff, D. & Stiling, P. (1996) Risks of species introduced for biological control. *Biological Conservation*, **78**, 185-192.

Vitousek, P.M. (1988). Diversity and biological invasions of oceanic islands. *Biodiversity* (ed E.O. Wilson), pp. 181-189. National Academy of Science, U.S.A., http://www.nap.edu/openbook/0309037395/html/181.html.

Williams, R.O. (1970) *Plants on St. Helena* Privately published.