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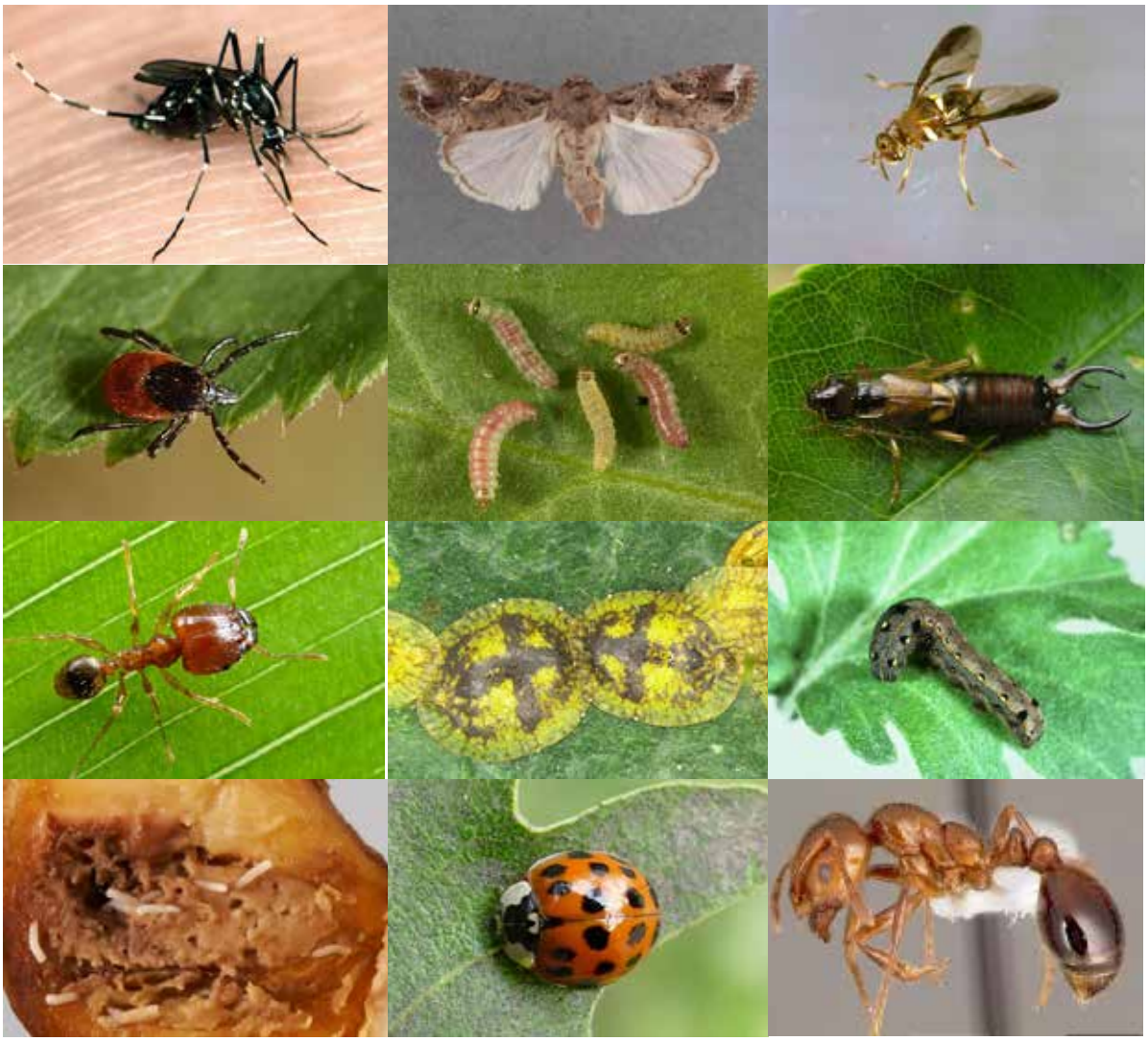
FIELD GUIDE TO INVASIVE ALIEN INVERTEBRATES IN THE SOUTH ATLANTIC UK OVERSEAS TERRITORIES

PART 1 – INTRODUCTION



Chris Malumphy, Sharon Reid, Rachel Down, Jackie Dunn, Debbie Collins and June Matthews

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Part 1 Introduction

Chris Malumphy, Sharon Reid, Rachel Down, Jackie Dunn, Debbie Collins and June Matthews

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Fera Science Ltd., National Agri-food Innovation Campus, Sand Hutton, York, YO41 1LZ, United Kingdom

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Frontispiece

Top row: Asian Tiger Mosquito *Aedes albopictus* adult © Susan Ellis, Bugwood.org; Fall armyworm *Spodoptera frugiperda* adult © Fera; Pumpkin fly *Dacus bivittatus* adult female © Fera. Second row: Sheep tick *Ixodes Ricinus* adult © Fera; South American tomato moth *Tuta absoluta* larvae © Fera; European earwig, *Forficula auricularia* adult male © Pudding4brains. Third row: Big-Headed Ant *Pheidole megacephala* worker © Alexander L. Wild; Brown soft scale *Coccus hesperidum* adult female © C. Malumphy; Fall armyworm *Spodoptera frugiperda* larva © Fera. Bottom row: Oriental Fruit Fly *Bactrocera dorsalis* adult © Fera; Harlequin ladybird *Harmonia axyridis* adults © Bugwood.org; Red Imported Fire Ant *Solenopsis invicta* worker © April Noble, Bugwood.org.

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PART 4 – INSECTS (bugs, ants, wasps, moths)

PART 5 – INVERTEBRATES (except insects) & REFERENCES

1. Purpose and scope

Invasive alien (also referred to as non-native or exotic) species are a major threat to biodiversity globally and particularly to the United Kingdom Overseas Territories (UKOTs). Early detection and identification of invasive alien species can enable effective and appropriate measures to be taken in a timely manner to eradicate, contain and/or manage the pests. The guide mainly deals with the detection and identification of invasive plant pests likely to have an economic impact, but also includes examples of species that could have a human health/social impact (e.g. mosquitoes) and a biodiversity/environmental impact (e.g. ants).

The main purpose of this guide is to assist early detection and identification of invasive species by:

- Providing pertinent information to enable the identification of the main groups of invertebrate plants pests;
- Providing information for the diagnosis of plant damage caused by invertebrate pests;
- Providing detailed factsheets on key invasive alien invertebrate pests that currently threaten plant health, human health and/or biodiversity in the UKOTs located in the South Atlantic;
- Providing information on specimen collection and preservation for further analysis;
- Providing sources of further information on invasive species
- Providing instructions on how to use the Fera identification service.

This guide is intended to be used by those working in biosecurity and plant health, and by all those interested in preserving the unique environments and biodiversity found in the UKOTs located in the South Atlantic Ocean. The guide will not enable the user to identify to species all the invasive alien invertebrates that they may encounter, but it does provide advice on how to collect and preserve specimens for further study and where to seek assistance.

The invertebrates included in this guide were selected from lists of priority economic, human and biodiversity threats identified for each UKOT in the South Atlantic during Horizon Scanning workshops held in Saint Helena and Cambridge (UK) during 2018, organised by the Centre for Ecology and Hydrology and GB Non-Native Species Secretariat (see Acknowledgements for details). The invertebrate species selected range from those adapted to Tropical, Subtropical, Temperate and Antarctic climates.

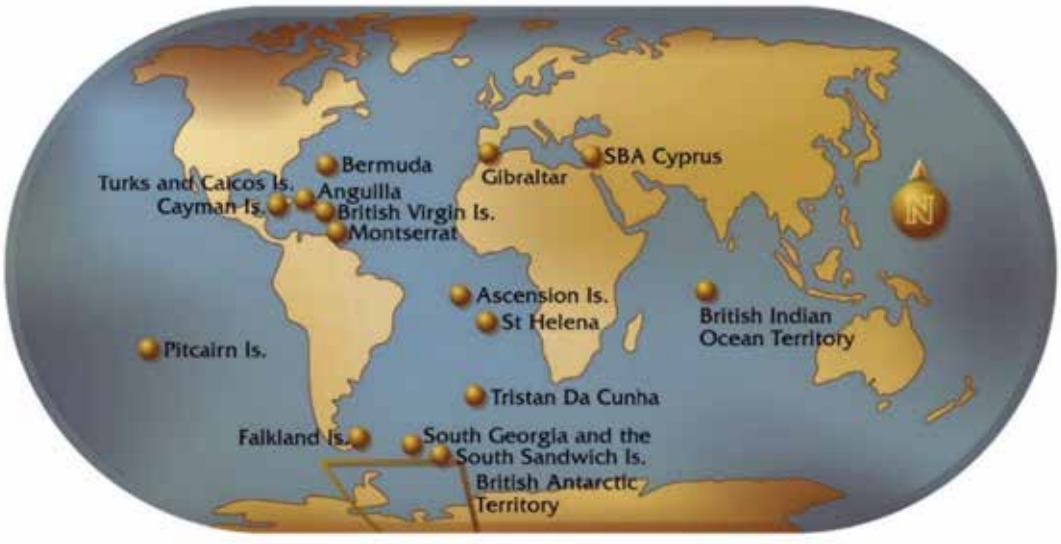


Figure 2.1.1 Map showing the location of the UK Overseas Territories and Crown Dependencies © Joint Nature Conservation Committee (JNCC)

2. Introduction

2.1 UK Overseas Territories and Biodiversity

There are 14 UKOTs spread across the World (Fig. 2.1.1) of which six are located in the South Atlantic Ocean: Ascension Island, Saint Helena, Tristan da Cunha, Falkland Islands, South Georgia and the South Sandwich Islands, and the British Antarctic Territory (BAT). The UKOTs support an amazing diverse range of unique ecosystems and habitats (Figs 2.1.2 and 2.1.4) and sustain many rare and threatened plant and animal species (Figs 2.1.3 and 2.1.4). It is estimated that over 90% of the UK's biodiversity is found in its Overseas Territories, with more priority ecosystem types occurring in the UKOTs than in the whole of metropolitan UK (Defra, 2012). The UKOTs in the South Atlantic Ocean are of particular significance because they have some of the most pristine ecosystems in the World.

As the UKOTs are mostly small islands, their biodiversity has evolved in isolation, resulting in a high proportion of endemic species, found nowhere else in the world. Weighell & Pelembe (2009) reported that over 340 endemic species have been found in the UKOTs, compared to about 60 in metropolitan UK. However, other sources record a much higher number of endemic species in the UKOTs, for example, Gray *et al*. (2018) record 450 endemic invertebrate species from Saint Helena alone (Fig. 2.1.3). A review by Pienkowski (2005) noted 61 sites in the UKOTs that met the criteria for Ramsar designation, indicating the global significance of the UKOT wetland habitats.

Further information on the UKOTs in the South Atlantic and their biodiversity can be obtained online from the following links:

- Joint Nature Conservation Committee (JNCC) – http://jncc.defra.gov.uk/page-4079
- UK Overseas Territories Conservation Forum (UKOTCF) – http://www.ukotcf.org/index.cfm
- Policy UK Overseas Territories – https://www.gov.uk/government/policies/uk-overseas-territories
- Kew Royal Botanic Gardens – UK Overseas Territories Programme – http://www1.kew.org/science/ukots/index.html
- GB Non-Native Species Secretariat – UK Overseas Territories Home – http://www.nonnativespecies.org/ots/otsMap.cfm
- Government of Ascension Island - http://www.ascension-island.gov.ac
- British Antarctic Territory - https://www.gov.uk/world/organisations/british-antarctic-territory
- British Antarctic Survey - https://www.bas.ac.uk/
- Government of South Georgia and the South Sandwich Islands - http://www.gov.gs/
- Government of Saint Helena - http://www.sainthelena.gov.sh/
- Saint Helena National Trust - http://www.trust.org.sh/
- Saint Helena Island information on endemic species - http://sainthelenaisland.info/endemics.htm
- Government of Tristan da Cunha - http://www.tristandc.com/government.php

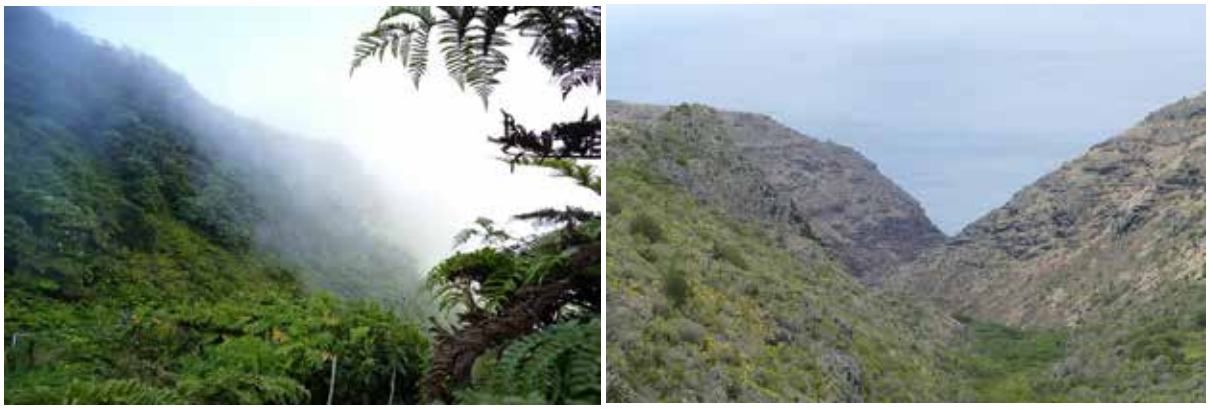


Figure 2.1.2 Saint Helena, cloud forest on Diana's Peak (left) and the arid Lemon Valley (right) © C. Malumphy

Figure 2.1.3 Saint Helena, examples of endemic invertebrates: spiky yellow woodlouse *Pseudolaureola atlantica*; blue leafhopper *Nehela vulturina*; and the blushing snail *Succinea sanctaehelenae* © C. Malumphy

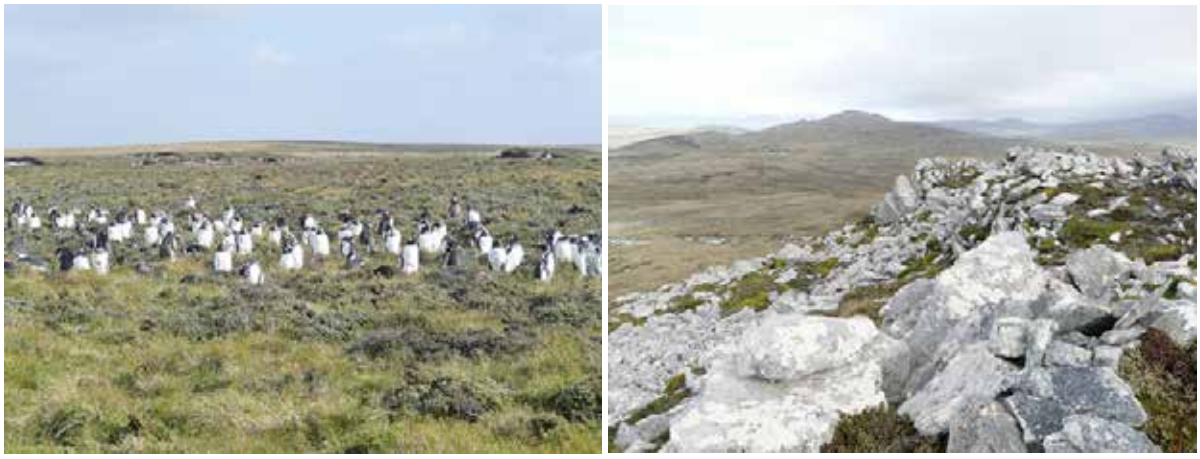


Figure 2.1.4 Falkland Islands, East Falkland, gentoo penguins *Pygoscelis papua* at Whale Point (left) and rugged treesless mixed heathland at Mount Longdon © C. Malumphy

2.2 Impact of invasive alien invertebrate pests

Invasive alien species are a major cause of biodiversity loss globally. Their impacts are often most severe on island environments typical of the UKOTs. Island species or populations are often vulnerable to the impacts of non-native species because of their previous isolation from predators, diseases or competitors. Indeed, the majority (72%) of global extinctions since 1500 have occurred on islands and, for example, 67% of threatened bird species are found on oceanic islands. A review of non-native species in the UKOTs indicated that there are a minimum of 2261 non-native species recorded as occurring across the UK Overseas Territories and Crown Dependencies (JNCC, 2007). The UKOTs contain over 500 globally threatened species, and many undisturbed habitats of international significance. Invasive alien species not only impact biodiversity but can also have a negative economic and social impact as illustrated below.

Biodiversity and environmental impacts

The introduction of invasive alien invertebrate plant pests into the UKOTs can have an enormous negative impact on the environment, in some cases permanently changing the ecology and reducing biodiversity. There have been a series of catastrophic declines of native plants in the UKOTs which are directly attributable to the introduction of invasive species by man, for example Bermuda's dominant tree species, Bermuda cedar (*Juniperus bermudiana*), declined by almost 95% between 1946 and 1956 following the introduction of juniper scale (*Carulaspis minima*), despite various attempts at biological control (Challinor & Wingate, 1971; Wingate, 2001, 2011). Fortunately, some natural regeneration still occurs from the small numbers of remaining Bermuda cedar which exhibit some resistance to the scale insect. It is hoped that Bermuda cedar will thus survive long enough to develop an inherent resistance, as have the closely-related mainland junipers. A similar catastrophic decline of about 90-95% of the dominant tree species, Caicos or Caribbean pine (*Pinus caribaea* var. *bahamensis*), has occurred in the Turks and Caicos Islands (TCI) from about 2005 onwards, following the accidental introduction of pine tortoise scale (*Toumeyella parvicornis*) (Malumphy *et al*., 2012) (Figs 2.2.1-2.2.2). The Caicos pine is the foundation species of the pine yard habitat, a globally endangered ecosystem on which many other plants, birds, reptiles, and insects depend. Action is being taken through the Caicos Pine Recovery Project to safeguard the future of the Caicos pine. More recently the endemic century plant (*Agave missionum*) has been almost wiped out from most areas of the British Virgin Islands (BVI) following the introduction of the agave snout weevil (*Scyphophorus acupunctatus*) (Fig. 2.2.3). This is currently being investigated by a team from Kew Gardens in collaboration with the National Parks Trust of the Virgin Islands. In the South Atlantic, the jacaranda bug or greenhouse orthezia (*Insignorthezia insignis*) was introduced into Saint Helena in the late 1980s where, in the absence of any natural enemies, it was killing the last remaining stands of the endemic gumwood, *Commidendrum robustum* (Booth *et al.,* 1995) (Fig. 2.2.4) (see Fact sheet 6.16). The trees were saved by the introduction of the exotic predatory coccinellid beetle, *Hyperaspis pantherina* Fürsch in a highly successful biological control programme (Shaw *et al*., 2001; Fowler, 1993, 2004, 2005; Wittenberg & Cock, 2005).

Figure 2.2.1 Healthy *Pinus caribaea* forest in the Bahamas © C. Malumphy

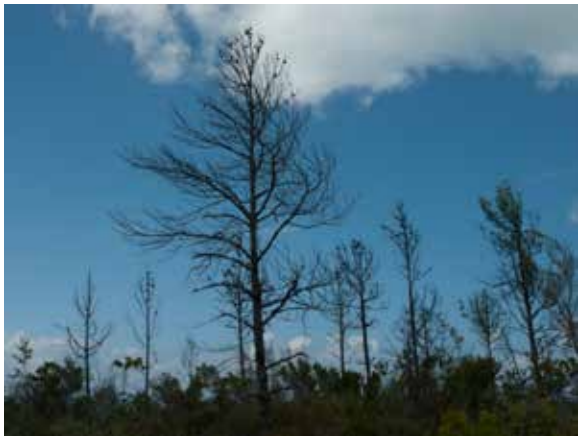


Figure 2.2.2 Dead and dying *Pinus caribaea* trees in the TCI due to a massive infestation of tortoise scale *Toumeyella parvicornis* © Dr Martin Hamilton, Kew

Figure 2.2.3 Endemic century plants *Agave missionum* killed by agave snout weevil *Scyphophorus acupunctatus*, BVI © C. Malumphy

Figure 2.2.4 Jacaranda bug *Insignorthezia insignis* threatened the survival of the endemic gumwood *Commidendrum robustum* in Saint Helena until controlled by the introduction of the ladybird *Hyperaspis pantherina* (inset) © C. Malumphy

Economic impacts

The pink hibiscus mealybug, *Maconellicoccus hirsutus*, was first reported in the Caribbean in 1994 in Grenada. This was the first record of the insect as a major pest in the New World. By the beginning of 2001, the pest had spread to over 25 territories from Guyana and Venezuela in the South to the Bahamas in the North (Williams, 1996). The pest has also extended its distribution to Central America and southern North America. It attacks more than 330 plant species (Chong, 2009), including many agricultural and horticultural crops. It caused estimated economic losses, which include crop losses, costs of control, and impact on trade, of $18.3 million (USD) in Grenada (1995–1998), $280,000 in St. Kitts (1995–1997), $5.1 million in Trinidad (1995–1997), $67,000 in St. Lucia and St. Vincent, and $3.4 million in the Grenadines (Kairo *et al*., 2000). Early attempts to control the pest using pesticides resulted in failure and a classical biological control approach was adopted. Several exotic natural enemies were introduced but control was attributed to the parasitoid wasp *Anagyrus kamali* and the ladybird *Cryptolaemus montrouzieri*. In all countries where biological control was implemented, this resulted in success.

More recent examples of invasive alien invertebrates in the Caribbean region are the papaya mealybug *Paracoccus marginatus*, which has become a pest in Antigua, St Kitts and Nevis, and the

British and US Virgin Islands *(Miller et al.*, 1999); and the Asian citrus psyllid *Diaphorina citri*, which has become widespread in the Caribbean since 1998 (CABI/EPPO, 2011), and is a vector of the very serious citrus huanglongbing (greening) disease caused by the bacterium *Liberibacter asiaticus*. The latter disease has had a massive impact in Florida where commercial citrus production is no longer viable in many areas.

Human health and social impacts

Mosquitoes, as vectors of human and animal pathogens, are a major concern to all the UKOTs with warmer climates and can have severe direct human health impacts and indirect social impacts (loss of income due to a reduction in tourism). This is discussed further in Fact Sheets 6.4 Yellow fever mosquito (*Aedes aegypti* (L.)), 6.5 Tiger mosquito (*Aedes albopictus* (Skuse)), 6.6 African malaria mosquito (*Anopheles gambiae* Giles complex) and 6.7 Common malaria mosquito (*Anopheles quadrimaculatus* Say).

The European earwig *Forficula auricularia* has become a considerable domestic and public nuisance in the Falkland Islands, due to large numbers of earwigs entering homes and causing significant problems for local horticulture by eating garden vegetable crops.

In the Turks and Caicos Islands the National Tree is the Caicos pine which has suffered a catastrophic decline following the introduction of pine tortoise scale (see section on environmental impact above).

The National tree of the British Virgin Islands is the White Cedar *Tabebuia heterophylla*. This tree was important because its wood was used to make the stern, stern posts and frame of the famous Virgin Islands sloops. The foliage of most white cedar plants has been severely galled by the recent introduction of the tabebuia thrips *Holopothrips tabebuia* reducing their aesthetic appearance. The tradition of using a mature century plant *A. missionum* as a Christmas tree in the BVI, by spraying it with silver paint and decorating it, has disappeared as the plant has become rare following the introduction of the agave snout weevil *S. acupunctatus*.

There was a significant social (and economic) impact in many territories in the Caribbean following the introduction of the pink hibiscus mealybug, *M. hirsutus*, due to a reduction in agricultural production and exports.

2.3 Pathways of introduction

There is relatively little detailed quantitative data available on the long distance natural dispersal of invertebrates. However, it certainly occurs, being facilitated by migrating birds, mammals, and insects and by air and water currents (rafting). However, natural pathways appear to be only a minor component of the recent and rapid global spread of invasive alien species in contrast with human-mediated dispersal. The highest risk pathway for most plant pest species is plant trade, particularly the movement of plants for planting. All the inhabited Atlantic UKOTs rely on importing food (including fruit and vegetables), which is a potential pathway for the introduction of plant pests. The recent opening of an airport on Saint Helena, may increase the risk of introducing pest and most of the UKOTs are visited by cruise ships.

2.4 Mitigating plant health risks

A detailed discussion of mitigating plant health risks is beyond the scope of this guide. A simple outline of a plant health strategy is presented below to provide a pre- to post-border biosecurity continuum. The pre-border component is very important as it is always beneficial to reduce the likelihood of a pest being introduced in the first place rather than addressing the consequences after its introduction. It should also be stressed that biosecurity is the responsibility of everybody involved with plants including the agricultural, horticultural and tourist industries, landowners, non-governmental organizations and the public. There needs to be a continual awareness of the risks, vigilance and involvement by all the stakeholders for a biosecurity strategy to be effective.

Pre-Border

- Evidence based and proportionate plant health legislation (including regulated pests and plants) to ensure the best protection for plant health.
- International collaboration to reduce the likelihood of pests arriving at the border in the first place.
- Horizon scanning to identify potential new pests and gain advance warning and intelligence.
- Effective and prompt sharing of information on new risks and pathways.
- Careful sourcing and selection of plant material.

Border

- Border inspections to reduce the risk of pests crossing the border, and feedback intelligence to Pest Risk Assessors.
- Targeted risk-based inspections of imported plant material.
- Develop and validate new detection and identification methods.
- Enhance collaboration between border force and trade to gain intelligence of pathways.

Inland

- Targeted surveillance to enable early detection of new pests.
- Developing better ways to respond and reduce the chance of establishment.
- Develop contingency plans and clear governance to eradicate or successfully manage outbreaks.
- Development of more resilient horticultural and agricultural sectors to increase the ability to manage pests and reduce the need for imports.
- Building resilience in the UKOTs and learning to live with established pests.

Further information on biosecurity and plant health threats may be obtained online from the following links:

- **IPPC – International Plant Protection Convention**
  https://www.ippc.int/en/

The IPPC is the phytosanitary standard setting organization referenced in the Sanitary and Phytosanitary Measures Agreement of the World Trade Organization (WTO). They have established International Standards for Phytosanitary Measures (ISPMs) (https://www.ippc.int/en/core-activities/standards-setting/ispms/) which provide guidance on all aspects of plant health. The IPPC also provides Phytosanitary Resources (http://www.phytosanitary.info/) including e-learning

modules, manuals, training materials, diagnostic protocols, videos, advocacy materials, photographs, a roster of consultants and databases of projects and activities.

- **European and Mediterranean Plant Protection Organization (EPPO)**
  https://www.eppo.int/

EPPO is an intergovernmental organization responsible for cooperation and harmonization in plant protection within the European and Mediterranean region. Under the International Plant Protection Convention (IPPC), EPPO is the regional plant protection organization (RPPO) for Europe.

2.5 Priority invasive alien invertebrate threats to the South Atlantic UKOTs

The invertebrates included in this guide were selected from lists of major economic, human and biodiversity threats identified for each UKOT in the South Atlantic during Horizon Scanning workshops held in Saint Helena and Cambridge (UK) during 2018. Species that present a priority threat are listed below for each territory.

Ascension Island

Species	Impact	Page
Asian subterranean termite – *Coptotermes formosanus*	Economic	82
Harlequin ladybird – *Harmonia axyridis*	Biodiversity	85
Yellow fever mosquito – *Aedes aegypti*	Human health, Economic	92
Tiger mosquito – *Aedes albopictus*	Human health, Economic	96
African malaria mosquito – *Anopheles gambiae* complex	Human health	101
Common malaria mosquito – *Anopheles quadrimaculatus*	Human health, Economic	104
Mediterranean fruit fly – *Ceratitis capitata*	Economic	111
Bigger pumpkin fly – *Dacus bivittatus*	Economic	119
Yellow crazy ant – *Anoplolepis gracilipes*	Biodiversity	146
Singapore ant – *Monomorium destructor*	Biodiversity	153
Tawny crazy ant – *Nylanderia fulva*	Biodiversity	156
Red imported fire ant – *Solenopsis invicta*	Biodiversity, Human health	162
Little fire ant – *Wasmannia auropunctata*	Biodiversity, Human health, Economic	166
Fall armyworm – *Spodoptera frugiperda*	Economic	173
Tomato leaf miner – *Tuta absoluta*	Economic	177

Saint Helena

Species	Impact	Page
Asian subterranean termite – *Coptotermes formosanus*	Economic	82
Yellow fever mosquito – *Aedes aegypti*	Human health, Economic	92
Tiger mosquito – *Aedes albopictus*	Human health, Economic	96

African malaria mosquito – *Anopheles gambiae* complex	Human health, Economic	101
Common malaria mosquito – *Anopheles quadrimaculatus*	Human health, Economic	104
Oriental fruit fly – *Bactrocera dorsalis*	Economic	107
Mango fruit fly – *Ceratitis cosyra*	Economic	115
Bigger pumpkin fly – *Dacus bivittatus*	Economic	119
Yellow crazy ant – *Anoplolepis gracilipes*	Biodiversity	146
Singapore ant – *Monomorium destructor*	Biodiversity	153
Red imported fire ant – *Solenopsis invicta*	Biodiversity, Human health	162
Little fire ant – *Wasmannia auropunctata*	Biodiversity, Human health, Economic	166
German wasp – *Vespula germanica*	Biodiversity, Human health	169
Fall armyworm – *Spodoptera frugiperda*	Economic	173
Tomato leaf miner – *Tuta absoluta*	Economic	177

Tristan da Cunha

Species	Impact	Page
European earwig – *Forficula auricularia*	Biodiversity	88
Tiger mosquito – *Aedes albopictus*	Human health, Economic	96
Big-headed ant – *Pheidole megacephala*	Biodiversity	159
German wasp – *Vespula germanica*	Biodiversity, Human health	169
Fall armyworm – *Spodoptera frugiperda*	Economic	173

Falkland Islands

Species	Impact	Page
Harlequin ladybird – *Harmonia axyridis*	Biodiversity	85
Black bean aphid – *Aphis fabae*	Economic	132
Mealy cabbage aphid – *Brevicoryne brassicae*	Economic	136
Potato cyst nematodes – *Globodera pallida* and *G. rostochiensis*	Economic	187
Brown or stone centipede – *Lithobius forficatus*	Biodiversity	191
Sheep tick – *Ixodes ricinus*	Human health, Economic	197

South Georgia and South Sandwich Islands

Species	Impact	Page
Springtail – *Hypogastrura manubrialis*		
European earwig – *Forficula auricularia*	Biodiversity	191

British Antartic Survey

Species	Impact	Page
Antarctic soil mite – *Nanorchestes antarcticus*	Biodiversity	195
Springtail – *Protaphorura fimata*	Biodiversity	204

3. An introduction to invertebrate plant pests

What is a plant pest? It is defined by the International Plant Protection Convention (IPPC) as 'Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products' (IPPC, 2007). With this broad definition, any invertebrate that feeds on, or otherwise damages, any living or dead plant material is a plant pest.

What is an invertebrate? It is an animal that neither possess' nor develops a vertebral column (commonly known as a backbone or spine). Familiar examples of terrestrial invertebrates include worms, slugs, snails, woodlice, land crabs, millipedes, centipedes, spiders, mites and insects. Within the UKOTs, the most important group of invertebrate plant pests are the insects, followed by the mites.

Accurate identification is important for biosecurity, pest management and risk assessment, as the correct name will link up with all the knowledge on the life cycle, host range, impact, natural enemies and appropriate management practices. An incorrect identification can result in the wrong pest risk assessment and inappropriate management action which can exacerbate the situation. The identification is particularly critical if a biological control program is going to be implemented.

3.1 Class Insecta – Insects

The great majority of insect plant pests are assigned to just five orders of insects: Coleoptera, Diptera, Hemiptera, Lepidoptera, and Thysanoptera. If you can recognize these five groups, you will be able to place the majority of insect plant pests that you encounter in the field into the correct Order. The main characters used to distinguish these orders are summarised in Table 3.1.

Order Coleoptera – Beetles

Figs 3.1.1-3.1.4.

This is the largest and most diverse order in the entire animal kingdom, with about 370 thousand species worldwide. Beetles are minute to large insects, normally with two pairs of wings of which the front ones (called elytra) are hard or leathery and meet neatly along the mid-line of the dorsal surface. The hind wings are membranous and folded out of sight beneath the elytra. The prothorax (section behind the head) is normally large and mobile. The mouthparts are of the biting type. Beetles are usually instantly recognizable although some bugs (Hemiptera: Heteroptera) are similar in appearance but may be distinguished by their overlapping front wings and sucking mouthparts. Beetles have a complete life-cycle with eggs, larvae (grubs), pupa and adults. This is the largest order of insects and contains many highly invasive plant pests.

Examples of beetle families that contain major plant pests include:

Family **Bostrychidae** – Auger beetles, False powder-post beetles, or Horned powder-post beetles
This family contains several pantropical wood boring and storage pests.

Family **Bruchidae** – Seed beetles
Many bruchids attack stored seeds such as beans and lentils.

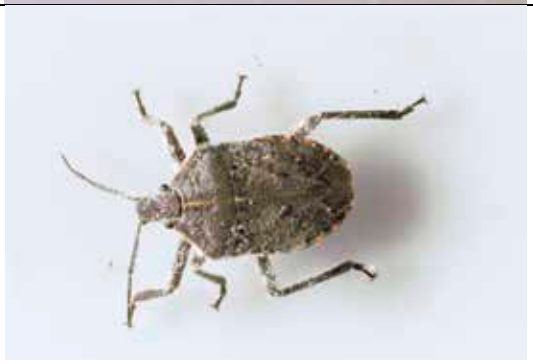
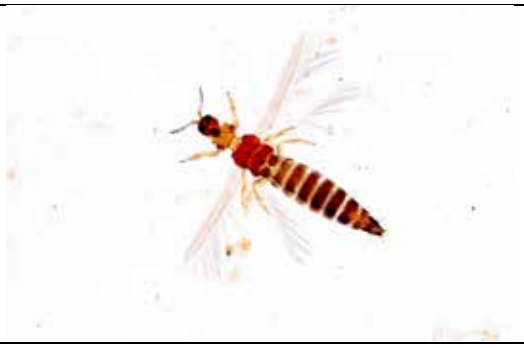
Coleoptera – Beetles Minute to very large insects, usually with hardened bodies. Forewings characteristically modified into hardened cases (elytra), which fold over and protect the membranous hindwings when at rest. Mouthparts are adapted for chewing. The larvae are known as grubs.	
Diptera – True flies Generally small insects, easily recognized by the membranous forewings in combination with hind wings that are modified to form a pair of small club-shaped halters used for balancing. Mouthparts are adapted for sucking. The larvae are known as maggots.	
Hemiptera – True bugs Small to medium sized insects with sucking mouthparts, two pairs of wings or reduced hind wings. In the Auchenorrhyncha and Sternorrhyncha, both pairs of wings (if present) are membranous; in the Heteroptera, the bottom half of the forewings is thickened, forming the hemelytra. Many Sternorrhyncha excrete masses of white wax.	
Lepidoptera – Butterflies and moths Minute to very large insects with elongate antennae and two pairs of large membranous wings, the entire body and wings are covered by scales. Mouthparts are generally elongated to form a long sucking proboscis, held coiled beneath the head when not in use. Many of the butterflies and moths are brightly coloured. The larvae are known as caterpillars.	
Thysanoptera – Thrips Minute insects with slender bodies and, usually two pairs of narrow, fringed wings. Sucking mouthparts. Commonly found in flowers.	

Table 3.1 Key characters used to recognize the five main orders of insect that contain the majority of invasive alien plant pests © Crown copyright

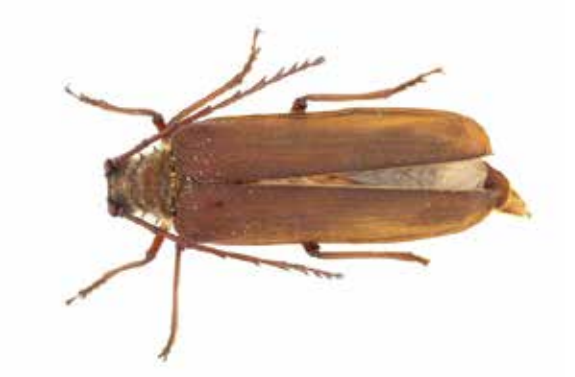


Figure 3.1.1 Longhorn beetle (Cerambycidae), Falkland Islands. The very long antennae are characteristic for the family © Crown copyright

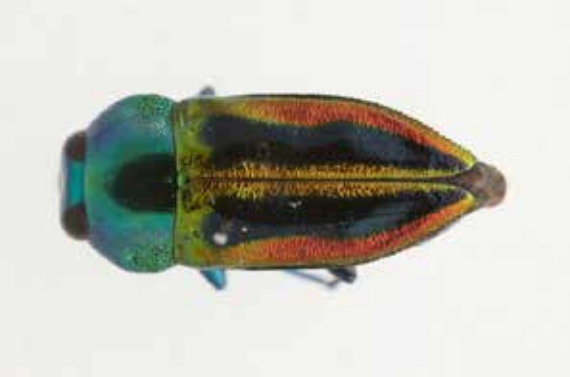


Figure 3.1.2 Jewel beetle *Ctenoderus maulicus* (Buprestidae), Falkland Islands © Crown copyright

Figure 3.1.3 Ground beetle *Hydromedion sparsutum* (Promecheilidae), South Georgia © C. Malumphy

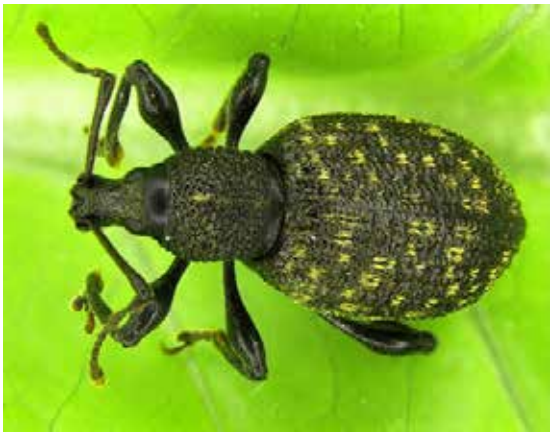


Figure 3.1.4 Black vine weevil *Otiorhynchus sulcatus* (Cucurlionidae), Falkland Islands © C. Malumphy

Family **Buprestidae** – Jewel beetles
This is a large, mainly tropical family, containing some of the most beautiful insects known as they are often bright metallic coloured. The larvae develop in wood and some species are major invasive forestry pests.

Family **Cerambycidae** – Longhorn beetles
There are over 26 thousand described species, and this is one of the most economically important families of beetles as the larvae tunnel into wood. Some are major pests of timber and forestry. They are usually recognizable by their extremely long antennae and the family contains some of the largest of all known insects.

Family **Chrysomelidae** – Leaf beetles, flea beetles
This is a large family containing more than 37 thousand species of leaf-feeding beetle, most of which are quite small. It contains many important invasive plant pests.

Family **Curculionidae** – Weevils, bark beetles, ambrosia beetles
This is a huge family with more than 82 thousand species. Most can be recognized by the well-marked rostrum or snout and elbowed, clubbed antennae. Many of the species are covered in tiny, brightly-coloured scales. The bark beetles (Scolytinae) are typically cylindrical and have a reduced rostrum. Ambrosia beetles carry a fungus on which they feed. The larvae of most species feed enclosed in roots, stems, seeds or under bark. Many species are serious pests of trees and stored products.

Family **Scarabaeidae** – Chafers, dung beetles, scarabs
This is one of the largest of all insect families, with over 19 thousand species. It also contains some of the largest and heaviest insects, and many species have beautiful metallic colouration, and bear extraordinary 'horns' that develop on the head and thorax.

Order Diptera – True flies

Figs 3.1.5-3.1.8.

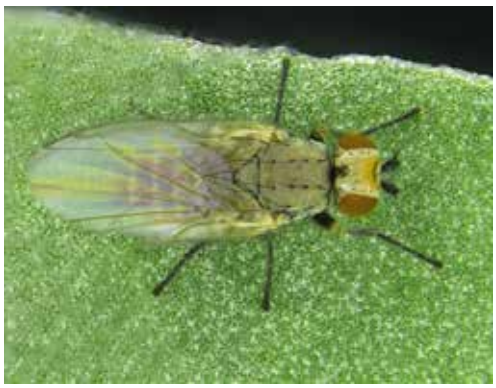


Figure 3.1.5 Chrysanthemum leafminer *Chromatomyia syngenesiae* (Agromyzidae), Falkland Islands © C. Malumphy

Figure 3.1.6 Fungus gnat *Ctenosciara* sp. (Sciaridae), Falkland Islands © C. Malumphy

Figure 3.1.7 Hoverfly *Eristalis croceimaculata* (Syrphidae), Falkland Islands © Crown copyright

Figure 3.1.8 West Indian fruitfly *Anastrepha obliqua* (Tephritidae) reared from *Mangifera indica*, Dominican Republic © Crown copyright

True flies are minute to medium sized insects with a single pair of wings (forewings) used to fly. The hindwings having evolved into minute dumbbell-shaped organs known as halteres, which act as high-speed sensors of rotational movement and allow dipterans to perform advanced aerobatics. Diptera is a large order with about 125 thousand species described. They have sucking mouthparts and a complete life-cycle with eggs, larvae (commonly known as maggots), puparia and adults.

Examples of fly families that contain major plant pests include:

Family **Agromyzidae** – Leaf mining flies
There are approximately 2,500 species and the larvae mine the foliage of various plants.

Family **Cecidomyiidae** – Gall midges
There are approximately six thousand species and the larvae of most gall midges feed within plant tissue, creating abnormal plant growths called galls.

Family **Tephritidae** – Fruit flies
There are nearly five thousand described species of fruit fly. They are small to medium-sized flies that are often colourful, and usually have pictured or patterned wings. This is one of the most economically important groups of insects in the tropics and subtropics because the larvae of most species develop in plant tissue, especially fruit. Many species are highly invasive.

Order Hemiptera – True bugs

Figs 3.1.9-3.1.16

The Hemiptera comprise some 50 to 80 thousand species and are one of the most morphologically and biologically diverse orders of insects. Most hemipterans feed on plants, using their sucking and piercing mouthparts to extract plant sap. Some are parasitic while others are predators that feed on other insects or small invertebrates. They have an incomplete life-cycle with eggs, nymphs and adults. One exception is the whitefly (Aleyrodidae) where the final (4^{th}) nymphal instar is called a pupa or puparium. Whitefly taxonomy is based on the morphology of this stage rather than the adult which is used for the rest of the Hemiptera. Many hemipterans vector plant pathogenic pathogens and many egest honeydew which serves as a medium for the growth of black sooty moulds. Hemipterans are very common in the UKOTs in the Caribbean.

Examples of hemipteran families that contain plant pests include:

Sub-order Heteroptera

Family **Pentatomidae** – Shield bugs or stink bugs
Large family of often brightly coloured, medium sized to large bugs with shield-shaped bodies. All are armed with stink glands.

Family **Tingidae** – Lace bugs
Most species are easily recognized by the delicate lace-like sculpturing of their wings and thorax. Most species are host specific.

Sub-orders Auchenorrhyncha and Sternorrhyncha

Family **Aleyrodidae** – Whiteflies
Very small insects with their body and wings covered in fine powdery white wax. Some species have banded wings or may have completely dark wings. The nymphs resemble scale insects (see below). Some species are important vectors of plant pathogenic viruses.

Family **Aphididae** – Aphids
Small, pear-shaped bugs. Wings (when present) are usually clear. Many species have two tubes (siphunculi) sticking out of their abdomen. They often have complicated life cycles with sexual and parthenogenetic generations, winged and wingless forms and alternating hosts. Some species are important vectors of plant pathogenic viruses.

Family **Cicadellidae** – Leaf hoppers or sharp shooters
Large family of mainly small bugs, many brightly coloured. This is one of the most economically important families due to the ability of many species to vector plant pathogens.

Family **Flatidae** – Plant hoppers or Moth bugs
Usually easily identified by very broad wings, often greenish but may appear grey due to a covering of wax. The nymphs often carry conspicuous tufts of white wax coming from the tip of their abdomen.

Figure 3.1.9 Southern green shieldbug *Nezara viridula* (Pentatomidae), Greece © C. Malumphy

Figure 3.1.10 Pieris lacebug *Stephanitis takeyai* (Tingidae) on *Pieris japonica*, UK © Crown copyright

Figure 3.1.11 Giant whitefly *Aleyrodicus* sp. (Aleyrodidae), BVI © C. Malumphy

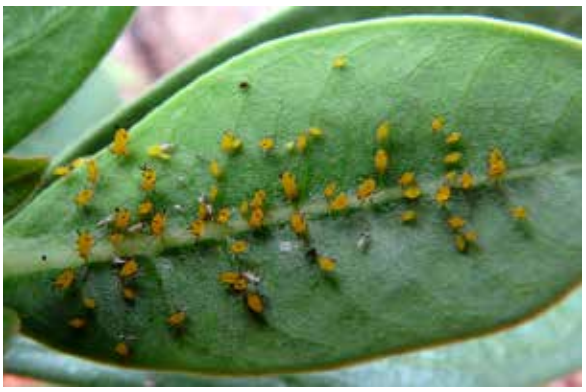


Figure 3.1.12 Oleander aphid *Aphis nerii* (Aphididae), Bahamas © C. Malumphy

Figure 3.1.13 A giant scale *Crypticerya genistae* (Monophlebidae), BVI © Fera

Figure 3.1.14 Barnacle scale *Ceroplastes cirripediformis* (Coccidae), BVI © Fera

Family **Psyllidae** – Plant suckers or jumping plant lice

Small to minute bugs with clear wings, that look like miniature cicadas. Many are host specific and feed on woody plants. The adults jump.

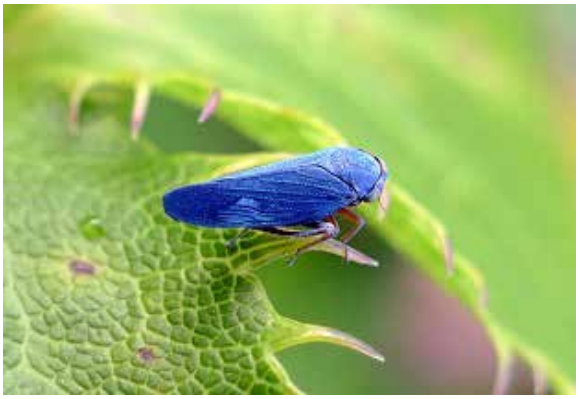


Figure 3.1.15 Vibrant blue leafhopper *Nehela vulturina* (Cicadellidae), Saint Helena © Fera

Figure 3.1.16 Damsel bug *Nabis paranensis* (Nabidae), Falkland Islands © Crown copyright

Super-family **Coccoidea** – Scale insects
Small to minute plant parasitic bugs assigned to several families. Adult females are wingless, some are mobile (Ensign scale insects and mealybugs) but most are immobile in the adult female stage (soft and armoured scales). Many produce protective waxy covers. Scale insects are very common in the tropics and subtropics.

Family **Asterolecaniidae** – Pit scales
Family **Coccidae** – Soft scale insects
Family **Diaspididae** – Armoured scale insects
Family **Monophlebidae** – Giant scale insects
Family **Ortheziidae** – Ensign scale insects
Family **Pseudococcidae** – Mealybugs
Family **Rhizoecidae** – Root mealybugs

Order Lepidoptera – Butterflies and moths

Figs 3.1.17-3.1.24.

There are about 180 thousand species assigned to the order Lepidoptera in 126 families, which account for 10% of the total described species of living organisms. It is one of the most widespread and instantly recognizable insect orders in the world, commonly known as the butterflies and moths. Adult lepidopteran species are characterized by several features, including scales (flattened hairs) covering their bodies and wings, and a proboscis (sucking mouthparts). The scales give butterflies and moths their extraordinary variety of colours and patterns. Almost all species have some form of membranous wings, except for a few that have reduced wings or are wingless. They have a complete lifecycle with eggs, caterpillars (or 'worms' in the Caribbean), pupae (or chrysalis if a butterfly), and the adult. Mating and the laying of eggs are carried out by adults, normally near or on the larval host plant. The caterpillars are completely different from their adult forms, having a cylindrical body with a well-developed head, mandible (biting) mouth parts, three pairs of thoracic legs and from none up to five pairs of prolegs. As they grow, these larvae change in appearance, going through a series of stages called instars. Once fully matured, the larva develops into a pupa. A few butterflies and many moth species spin a silk case or cocoon prior to pupating, while others do not, instead going underground. Once the pupa has completed its metamorphosis, a sexually mature adult emerges.

Examples of lepidopteran families that contain plant pests include:

Family **Crambidae** – Grass moths
Small moths which are variable in appearance. Some rest with closely folded wings and are inconspicuous, while others are brightly coloured and patterned, and rest with their wings spread. This family is closely related to the Pyralidae (see below) and many species are pests of crops while others are beneficial, helping to control invasive weeds.

Family **Gracillariidae** – Leaf mining moths
Small moths whose larvae mine leaves and stems. It contains several economic, horticultural and environmental pests. Some species are highly invasive.

Family **Noctuidae** – Owlet moths, cutworms or armyworms
This is a large family containing more than 11 thousand species. The adults are medium sized to large moths and are typically drab or camouflaged in colour. Many species are considered major agricultural pests around the world. Their larvae are typically known as "cutworms" or "armyworms" due to enormous swarms that destroy crops, orchards and gardens every year.

Family **Pyralidae** – Pyralid or snout moths
The adults are medium sized to large moths. Many species are economically important agricultural and storage pests.

Family **Sphingidae** – Hawk moths, sphinx moths or hornworms
The adults are moderate to very large in size and are distinguished among moths for their rapid, sustained flying ability. Their narrow wings and streamlined abdomens are adaptations for rapid flight. The caterpillars are equally large and impressive. Most only feed on a narrow range of hosts and they are only occasional pests.

Family **Tortricidae** – Tortrix moths or leafroller moths
This is a large family containing more than 10 thousand species. They are small or medium sized moths that rest with their wings folded back, producing a rather rounded profile. Many of these are economically important agricultural pests.

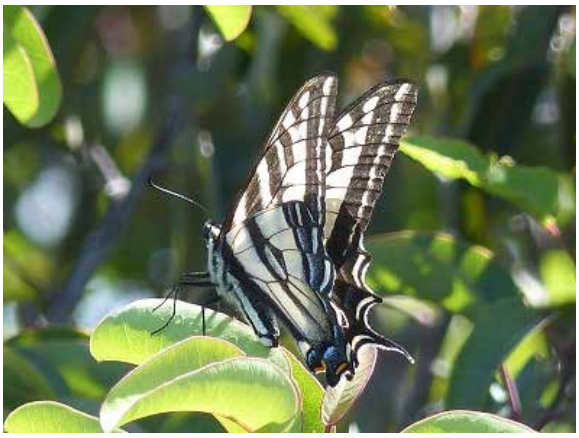


Figure 3.1.17 Pale swallowtail butterfly *Papilio eurymedon* (Papilionidae), USA © C. Malumphy

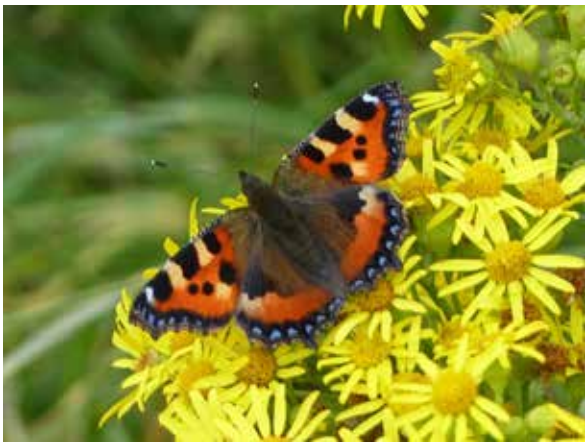


Figure 3.1.18 Small tortoiseshell butterfly *Aglais urticae* (Nymphalidae), UK © C. Malumphy

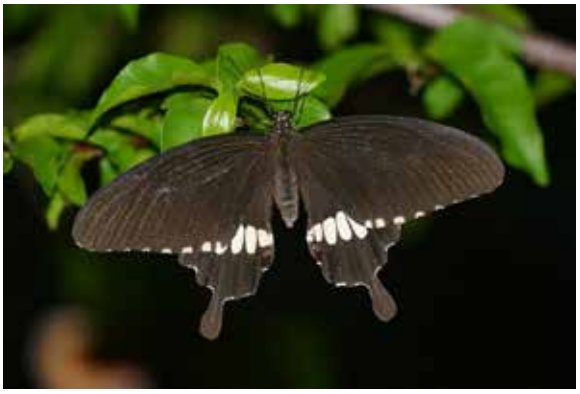


Figure 3.1.19 Common Mormon butterfly *Papilio polytes* (Papilionidae), Singapore © C. Malumphy

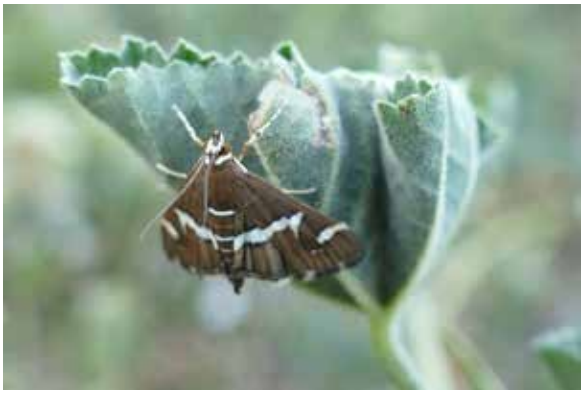


Figure 3.1.20 Beet webworm moth *Spoladea recurvalis* (Crambidae), Canary Islands © C. Malumphy

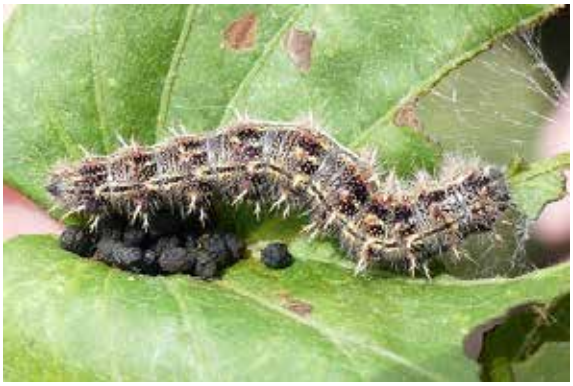


Figure 3.1.21 Painted lady butterfly *Vanessa cardui* (Nymphalidae) caterpillar, Saint Helena © C. Malumphy

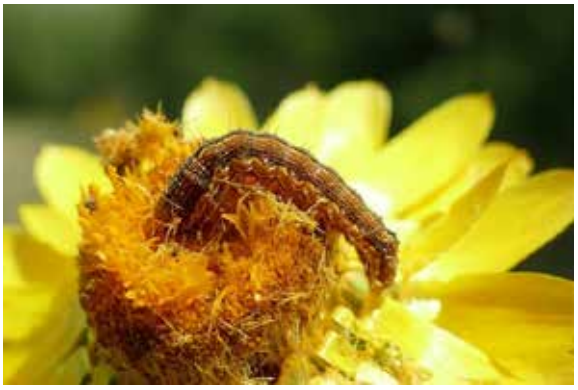


Figure 3.1.22 Cotton bollworm *Helicovera armigera* (Noctuidae) caterpillar, Saint Helena © C. Malumphy

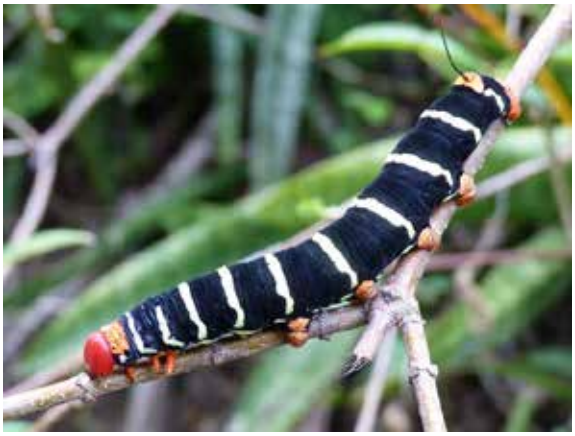


Figure 3.1.23 Tetrio sphinx *Pseudosphinx tetrio* (Sphingidae) caterpillar, Saint Lucia © C. Malumphy

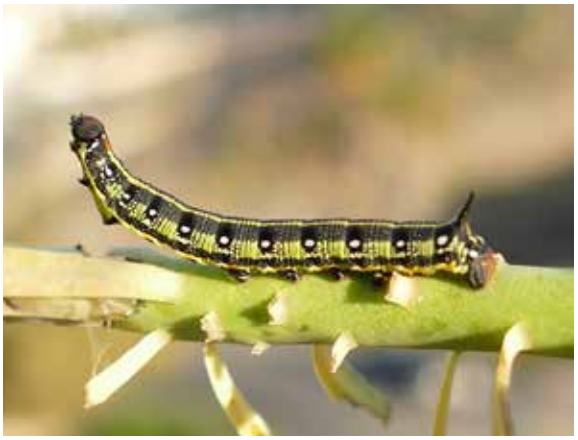


Figure 3.1.24 Spurge hawk-moth *Hyles euphorbiae* (Sphingidae) caterpillar, Canary Islands © C. Malumphy

Order Thysanoptera – Thrips

Figs 3.1.25-3.1.26

Thrips are minute, slender insects with fringed wings and unique asymmetrical mouthparts. Most species feed on plants by puncturing and sucking up the contents, although a few are predatory.

Approximately six thousand species have been described. They are weak fliers but are frequently moved with plant trade. Many species are pests of commercially important crops. A few species serve as vectors for plant pathogenic viruses, especially the Tospoviruses. Some species of thrips are beneficial as pollinators or as predators of other insects or mites. In the right conditions, such as in greenhouses, many species can exponentially increase in population size and form large swarms because of a lack of natural predators coupled with their ability to reproduce asexually. Identification to species is usually only possible morphologically by examination of a slide-mounted specimen under a high-power microscope by a specialist.

Family **Phlaeothripidae**
This family contains approximately 3400 species and may be distinguished from the Thripidae by the last abdominal segment being modified into a tube-like structure, and generally being a larger size. Many species are harmless fungi feeders, but many others induce plant galls in which they complete their life-cycle.

Family **Thripidae**
This family contains more than 2000 species and may be distinguished from other thrips by a saw-like ovipositor curving downwards, narrow wings with two veins, and antennae of six to ten segments with stiletto-like forked sense cones on antennal segments III and IV. They generally live and feed within narrow spaces at the base of leaves and within flowers. Several species are major economic agricultural pests.

Figure 3.1.25 Cuban laurel thrips *Gynaikothrips ficorum* (Phlaeothripidae) adult female inside leaf gall on *Ficus microcarpa*, Cyprus © C. Malumphy

Figure 3.1.26 Melon thrips *palmi* (Thripidae) adult female reared in culture under licence in the UK © Crown copyright

Other groups of insects

Order Dermaptera – Earwigs

Figs 3.1.27-3.1.28

There are about two thousand species of earwig described assigned to 12 families. Earwigs are easily recognised by their characteristic cerci, a pair of forceps-like pincers on their abdomen, and membranous wings folded underneath short, rarely used forewings. Earwigs are found on all continents except Antarctica. Earwigs are mostly nocturnal, feeding on a wide variety of insects and plants. They can damage foliage, flowers, and various crops. Many earwig species display maternal care, which is uncommon among insects. Female earwigs may care for their eggs, and even after they

have hatched as nymphs will continue to watch over offspring until their second molt. As the nymphs molt, sexual dimorphism such as differences in pincer shapes begins to show.

Figure 3.1.27 European earwig *Forficula auricularia* adult male (Forficulidae), Falkland Islands © C. Malumphy

Figure 3.1.28 Group of European earwigs *Forficula auricularia* in a glasshouse, Falkland Islands © C. Malumphy

Order Isoptera – Termites or white ants

Figs 3.1.29-3.1.31

There are more than three thousand species of termite described. They are eusocial insects that divide labour among castes consisting of sterile male and female 'workers' and 'soldiers'. All colonies have fertile males called 'kings' and one or more fertile females called 'queens'. They usually feed on dead plant material and cellulose, generally in the form of wood, leaf litter, soil or animal dung. Most species are not plant pests and are important in recycling of wood and plant matter. Many species are economically significant as they can cause serious damage to buildings, crops, or plantation forests. They have an incomplete life-cycle and biting mouthparts. Their soil trails and nests are ubiquitous in the Caribbean.

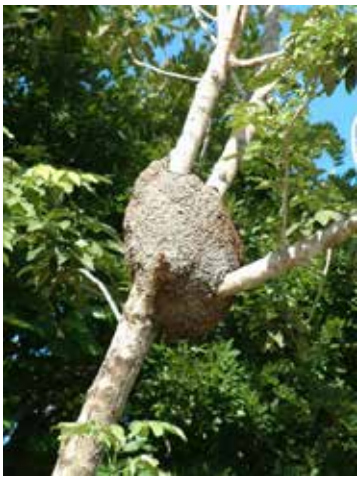


Figure 3.1.29 Termite nest in tree, Mexico © C. Malumphy

Figure 3.1.30 Termite soil trails on a tree, Mexico © C. Malumphy

Figure 3.1.31 Termite nest in tree, BVI © C. Malumphy

Order Hymenoptera – Ants, bees, wasps and sawflies

Figs 3.1.32-3.1.33

Family **Formicidae** – Ants
This family contains more than 12 thousand species. They are easily identified by their elbowed antennae and the distinctive node-like structure that forms their slender waists. They are eusocial insects that divide labour among castes consisting of sterile female 'workers', 'soldiers' and other specialised groups. Nearly all ant colonies also have one or more fertile females called 'queens' and some fertile males called 'drones'. The majority of ants are not direct plant pests, although some, such as leaf cutter ants, can be important agricultural pests. Many species are highly invasive and frequently reside in buildings.

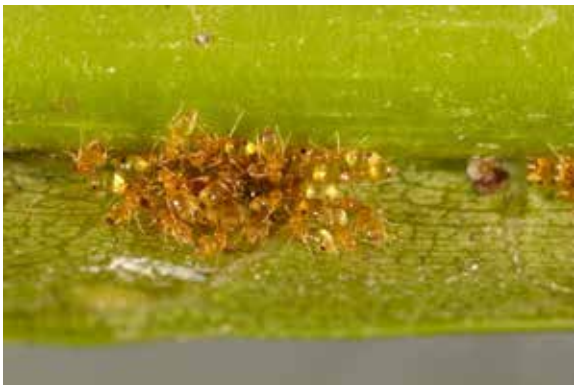


Figure 3.1.32 Little yellow ant *Plagiolepis allauadi* (Formicidae), UK © Fera

Figure 3.1.33 *Crematogaster scutellaris* (Formicidae), intercepted in UK © Fera

Order Orthoptera – Grasshoppers, locusts, crickets and Katydids

Figs 3.1.34-3.1.35

There are more than 20 thousand species of Orthoptera described worldwide. They have an incomplete metamorphosis, biting mouthparts and produce sound by rubbing (stridulating) various parts of their wings and/or legs against each other. They cannot fold their wings, which are held along their bodies, and most have enlarged hind legs for jumping. Some locusts can form large swarms and be important agricultural and horticultural pests.

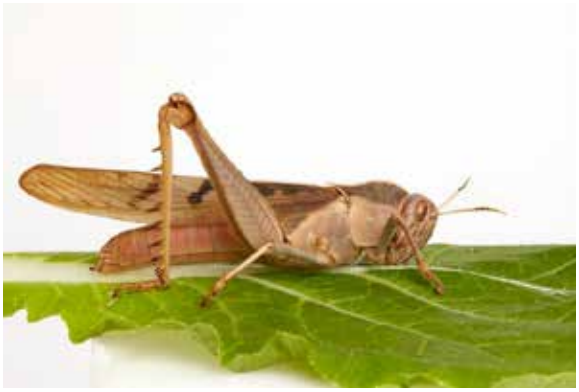


Figure 3.1.34 Brown headed bird locust *Acanthacris ruficornis* (Acrididae), Kenya © Fera

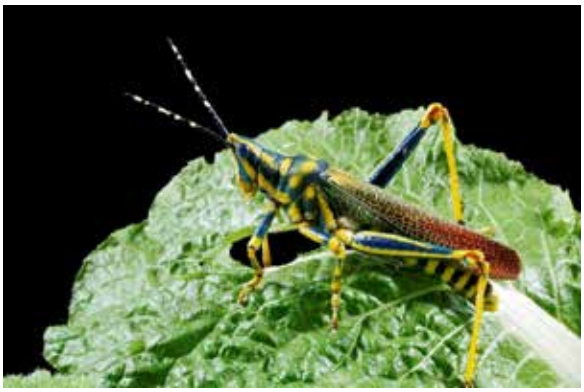


Figure 3.1.35 Painted grasshopper *Poekilocerus pictus* (Pyrgomophidae), India © Crown copyright

3.2 Class Arachnida, Subclass Acari – Mites

Figs 3.2.1-3.2.2

The subclass Acari (or Acarina) is a diverse group of arachnids that contains mites and ticks. Adult mites are very small, most have four pairs of legs and their mouthparts may be adapted for biting, stinging, sawing or sucking. Mites occupy a wide range of ecological niches and feed on a wide variety of materials including living and dead animal, plants and fungi and, lichens and some are parasites of plants and animals. There are more than 50 thousand species described worldwide.

Family **Eriophyidae** – Gall or rust mites
This is a large family containing about 3,600 species of plant parasites, many induce plant galls. They are dispersed naturally by wind. Many are major agricultural pests.

Family **Tenuipalpidae** – Flat mites or False spider mites
This family is closely related to the spider mites and contains several major agricultural and horticultural pests.

Family **Tetranychidae** – Spider mites
There are over a thousand species of spider mite. They generally feed on the lower surface of leaves where they spin protective silk webs. Many species of spider mites are major agricultural and horticultural pests.

Figure 3.2.1 *Tetranychus* sp. (Tetranychiidae) on shrub, BVI © C. Malumphy

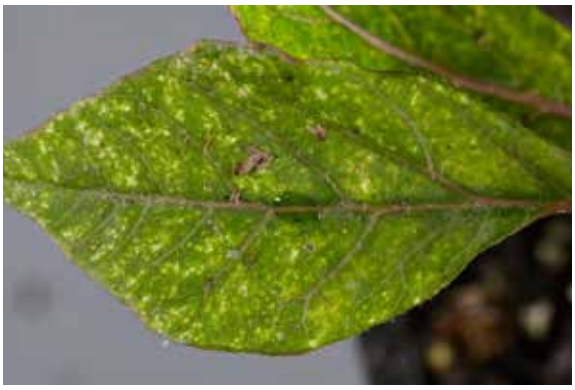


Figure 3.2.2 Lewis mite *Eotetranychus lewisi* (Tetranychiidae) feeding damage on *Euphorbia*, UK © Fera

3.3 Other groups of invertebrate plant pests

Phylum Nematoda – Nematodes or round worms

Figs 3.3.1-3.3.2

Nematodes are microscopic worms that shed their cuticle as they grow. They are one of the most important groups of invertebrate plant pests as many species parasitize plants. They are often overlooked as they are microscopic, difficult to detect and identify, and the symptoms they cause are often non-specific. Field identification of nematodes is beyond the scope of this guide and the following paragraph merely provides a brief introduction to the group.

Nematodes feed on all parts of the plant, including the roots, stems, leaves, flowers and seeds. They feed in a variety of ways and may be endo- or ectoparasitic but all use a specialized spear-like

mouthpart called a stylet. Nematodes often pierce and withdraw the contents of plant cells, killing them in the process. When this type of feeding occurs, large lesions are formed in the plant tissue. Some nematodes do not kill the plant cells they feed upon but induce the plant cells to enlarge and grow, thus producing one or more nutrient-rich feeding cells (giant cells) for the nematode. Many plant-parasitic nematodes feed on the roots of plants. The feeding process damages the plant's root system and reduces the plant's ability to absorb water and nutrients. Typical nematode damage symptoms are a reduction of root mass, a distortion of root structure and/or enlargement of the roots. Nematode damage of the plant's root system also provides an opportunity for other plant pathogens to invade the root and thus further weaken the plant. Direct damage to plant tissues by shoot-feeding nematodes includes reduced vigour, distortion of plant parts, and death of infected tissues depending upon the nematode species. The aboveground symptoms of nematode damage to roots are relatively generic or nondescript, including nutrient deficiency, incipient wilt, stunting, poor yield and sometimes plant death. Few diagnostic signs and symptoms of plant damage by nematodes exist except root galls, cysts, 'nematode wool', and seed galls. Thus, damage to crops by root-infesting nematodes often goes unnoticed by growers. Field patterns of nematode damage to roots begin in a small area and spreads radially from the initial infection site, often assisted by farm equipment. The only way to accurately diagnose nematode disease is to sample soil and plant material from suspected sites, extract nematodes for analysis and examine under a microscope.

Figure 3.3.1 Leaf and bud nematode *Aphelenchoides ritzemabosi* feeding damage on *Weigela*, UK © Crown copyright

Figure 3.3.2 Leaf and bud nematodes *Aphelenchoides* sp. in solution, extracted from leaf tissue, UK © Crown copyright

Class Gastropoda – Slugs and snails

Figs 3.3.3-3.3.4

Gastropods are found in marine and fresh water environments and on land. Terrestrial slugs and snails are frequently moved with plant trade and some species are invasive. Snails can be readily recognized as they have a hard-coiled shell in which they can completely retract their bodies for protection. Slugs do not possess an external shell. Only a relatively small number of slug and snail species are agricultural and horticultural pests.

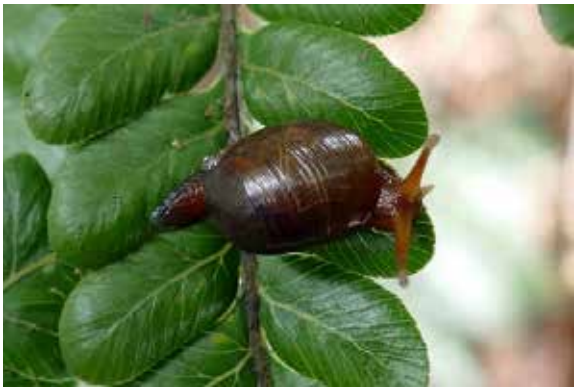


Figure 3.3.3 Saint Helena blusinhing snail *Succinea sanctaehelenae*, Saint Helena © C. Malumphy

Figure 3.3.4 *Neritina* (*Vitta*) *virginea* (Neritidae), TCI © Crown copyright

Class Diplopoda – millipedes

Figs 3.3.5-3.3.6

Millipedes are arthropods that are characterised by having two pairs of jointed legs on most body segments. Most millipedes have elongated cylindrical or flattened bodies with more than 20 body segments, while pill millipedes are shorter and can roll into a ball. Most millipedes are detritivores, that is they eat decaying leaves and other dead plant matter, and are thus not plant pests. Some can cause severe damage to seedlings while others can occur in huge numbers after rain and invade buildings. They can therefore be plant pests or cause a nuisance.

Figure 3.3.5 Giant black millipede *Anadenobolus arboreus* (Rhinocricidae), BVI © C. Malumphy

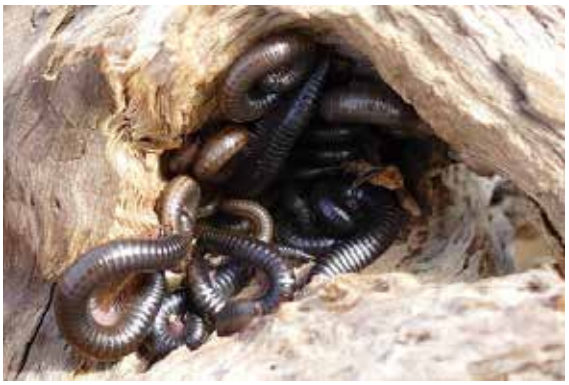


Figure 3.3.6 Millipedes hiding in some dead wood (Julidae), Saint Helena © C. Malumphy