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FIELD GUIDE TO INVASIVE ALIEN PLANT PESTS IN THE CARIBBEAN UK OVERSEAS TERRITORIES

PART 3 – INSECTS (except Hemiptera)

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

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Frontispiece
Top row: Giant African land snail *Lissachatina fulica* © C. Malumphy; Mediterranean fruit fly *Ceratitis capitata* © Crown copyright; Sri Lankan weevil, *Myllocerus undecimpustulatus undatus* adult © Gary R. McClellan. Second row: Cactus moth *Cactoblastis cactorum* caterpillar © C. Malumphy; Cottony cushion scale *Icerya purcashi* © Crown copyright; Red palm mite *Raoiella indica* adults © USDA. Third row: Tomato potato psyllid *Bactericera cockerelli* © Fera; Cotton bollworm *Helicoverpa armigera* © Crown copyright; Croton scale *Phalacrococcus howertoni* © C. Malumphy. Bottom row: Red palm weevil *Rhynchophorus ferrugineus* © Fera; Tobacco whitefly *Bemisia tabaci* © Crown copyright; Brown marmorated stink bug *Halyomorpha halys* © David R. Lance, USDA APHIS PPQ, Bugwood.org.

Contents

6. Invasive alien invertebrate species

Illustrated fact sheets are provided for 50 species of invasive alien invertebrate species that pose a potential plant health risk to some or all of the UKOTs in the Caribbean region. Selecting the species was challenging as there were hundreds of invertebrate plant pests to choose from. For example, there are more than 50 species of alien fruit flies (Tephritidae) alone that pose a plant health risk to the Caribbean. Many of the pest species were selected from the Global Invasive Species Database (http://www.invasivespecies.net/database/welcome/) and others were encountered by the first author during field work in the Caribbean. The pests were selected to cover the wide range of groups of potential invertebrate plant pests (snails, millipedes, mites and insects) that may be encountered. Some of the pests are already established in parts of the Caribbean but have not been recorded from all the UKOTs, whereas others have never been recorded from anywhere in the Americas. Some are polyphagous whereas others are host specific (particularly gall-forming species). Some are agricultural and horticultural pests whereas other are likely to have a bigger impact on the environment.

Each fact sheet provides information on the geographical distribution, host plants, biology, dispersal and potential impact. Photographs, descriptions and information on detection are provided to assist with phytosanitary inspections.

In the top right-hand corner of each datasheet is a table showing the presence or absence of the pest in each of the territories. It also indicates the type of major threat is presents to each territory. The table below indicates that the species discussed in the datasheet does not occur in any of the UKOTs in the Caribbean and it poses a biosecurity threat to the Turks and Caicos Islands. It may also have an impact on the biodiversity of the other territories, but it is not expected to have a major impact.

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			
Ber	¡			
BVI	¡			
Cay	¡			
Mon	¡			
TCI	¡	ü		

Abbreviations

Ang = Anguilla; Ber = Bermuda; BVI = British Virgin Islands; Cay = Cayman Islands; Mon = Monserrat; and TCI = Turks and Caicos Islands

Bio = Biodiversity (Environmental) Threat; Hlth = Human Health Threat; Econ = Economic (Agricultural) Threat

INSECTS

6.1 Brown Mulberry Longhorn Beetle

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Order: Coleoptera
Family: Cerambycidae
Species: *Apriona germari* (Hope)

Figure 6.1.1 *Apriona germari* larva inside its tunnel (left) and adult feeding on mulberry (right) © Franck Hérard

Background

Apriona germari is a wood-boring pest that feeds on living hardwood trees. It has several common names including brown mulberry longhorn beetle, longhorn stem borer, jackfruit longhorn beetle and mulberry longicorn beetle. Like other longhorn beetles, brown mulberry longhorn adults lay eggs under the bark on host trees. After egg hatch, the developing larvae feed under the bark forming tunnels or galleries. Later larval stages also bore into the woody tissue. Over time, the feeding activity of the larvae in the wood cause a decline in the health of trees and ultimately death. It has been intercepted on many occasions in Europe on wood packaging material imported from Asia. The potential pathway of introduction into the Caribbean is with woody plants for planting or with wooden packaging (dunnage). *Apriona germari* is just one example of a range of longhorn beetles that pose a threat to plant health in the UKOTs in the Caribbean.

Geographical Distribution

Apriona germari is native to Asia and occurs in the following countries: Cambodia, China, India, Korean Republic, Laos, Malaysia, Myanmar, Nepal, Pakistan, Taiwan, Thailand and Vietnam. It is not known to occur anywhere in the Americas.

Figure 6.1.2 U-shaped oviposition incision and egg pit of *Apriona germari* on small branch of mulberry tree in South Korea © Franck Hérard

Figure 6.1.3 *Apriona germari* larva © Zhangjing Chen

Figure 6.1.4 *Apriona germari* adult © Maurice Wong

Figure 6.1.5 *Apriona germari* adult and feeding damage on small branch of mulberry tree in southern South Korea © Franck Hérard

Host Plants

Apriona germari is polyphagous and has been recorded feeding on plants assigned to at least thirty-six genera in nineteen plant families. The families that contain the most host species are Moraceae, Rosaceae, Salicaceae and Ulmaceae. Host species include mulberry (*Morus* spp.), poplar (*Populus* spp.), *Lagerstroemia* spp., walnut (*Juglans* spp.), willow (*Salix* spp.), apple (*Malus* spp.), pear (*Pyrus* spp.), citrus (*Citrus* spp.), rosewood (*Dalbergia* spp.), hawthorn (*Crataegus* spp.), elm (*Ulmus* spp.), fig (*Ficus* spp.), paper mulberry (*Broussonetia papyrifera*), jackfruit (*Artocarpus heterophyllus*) and pagoda tree (*Styphnolobium japonicum*). It should also be noted that the host range has two elements: the species on which larvae can develop to maturity and the species on which adults carry out their maturation feeding. Mulberry (*Morus* spp.), paper mulberry (*Broussonetia papyrifera*) and wolfberry (*Lycium* spp.) are considered the main trees for maturation feeding of adult *A. germari*.

Description

Apriona germari adults are about 26 to 50 mm long (Figs 6.1.1 and 6.1.4-6.1.5). The body is black, but it appears orangey brown to greenish-yellow due to a dense covering of coloured hairs. These hairs can wear off in older specimens revealing the back body beneath. The antennae are brownish black with whitish grey rings and can be up to one third longer than the body. *Apriona germari* eggs are about 8-9 mm long, with a brown tinge. Eggs are laid in slits made in the bark by the female adult beetle (Fig. 6.1.2). The larvae look like legless grubs and can grow up to 70 mm long (Figs 6.1.1 and 6.1.3).

Biology

In China, the length of the lifecycle varies with climate and latitude. The further north *A. germari* is found, the longer it takes for a generation to develop. It is considered that a single generation takes 2–3 years to develop. Adults emerge between July and October. Females mate and lay eggs 10–15 days after emergence. Eggs are laid under the bark, in oviposition slits chewed out by the female (Fig. 6.1.2). Larvae feed first in the sapwood and then bore into the heartwood, with small frass expulsion holes made through the bark. Several larvae may be present in the same tree. The overwintering stage is the egg or larva. The pupal stage of *A. germari* occurs between the middle of June and the middle of August.

Dispersal and Detection

There is not much data on the capacity for natural spread of *A. germari*. One survey suggests that 400 m is a safe distance from a source site of *A. germari* (Fengxin *et al.*, 1997). However, another field survey accompanied with bait revealed that adults of *A. germari* can fly as far as 2500 m for food, although most individuals were caught between 250 and 550 m (Ruitong *et al.*, 1998).

This insect can be transported with plants and wood products containing bark, including wood, wood packaging, wood chips and firewood, moving in international trade. It is regularly intercepted in Europe on wood packaging material from Asia.

Economic and other Impacts

The main damage associated with *A. germari* is caused by the larvae, which bore into the wood soon after hatching, creating long tunnels. This affects the growth of the trees, causing weakness, and decreases the longevity of the tree. Weakness in the tree increases the chances of wind break potentially resulting in broken stems and trunks. Ultimately the tree may die. The quantity and quality of the timber is reduced such that it becomes unsuitable for commercial use, and entry of fungi and pathogens in the galleries cause discoloration of the wood. In China, *A. germari* is considered a serious threat to agriculture and forestry, especially to poplar plantations and fruit production (especially figs). *Apriona germari* can attack healthy trees as well as trees under stress. In the Caribbean, weakened trees are particularly susceptible to being completely broken up and uprooted by strong winds in the hurricane season.

6.2 Monkey pod round-headed Borer

Order: Coleoptera
Family: Cerambycidae
Species: *Xystrocera globosa* (Olivier)

	Present l Absent ¡	Threat Bio	Threat Hlth	Threat Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.2.1 Adult monkey pod round-headed borer *Xystrocera globosa*, Japan © natural-japan.net

Background

Xystrocera globosa is a stem-boring longhorn beetle that is a pest of a wide range of wild and cultivated leguminous trees. Its larvae infest the sapwood of several tree species, most notably monkey pod trees (*Albizia saman*), which is also commonly known in the Caribbean as saman trees. The beetle has several common names including monkey pod round-headed borer, monkey pod round-headed long horn beetle, Japanese green lined albizzia longicorn and two-lined albizzia long horn beetle. It is often trees that are stressed by factors such as drought that are most susceptible to attack by the beetle. This is because in healthy trees, strong flowing sap deters the insects from boring into the wood as they might drown; sap flow in stressed trees is often reduced, allowing the insect to bore into the wood. When trees are attacked, the individual infested limbs can die, but typically the tree itself will survive. If the infected limb is showing obvious signs of decline, removal of that infested branch is recommended as weakened trees in the Caribbean are susceptible to damage during the hurricane season.

The beetle has recently been found in Puerto Rico and therefore poses an immediate plant health risk to all the UKOTs in the Caribbean.

Figure 6.2.2 *Xystrocera globosa larva* © Greg Bartman, USDA APHIS PPQ

Figure 6.2.3 Adult *Xystrocera globosa* © Greg Bartman, USDA APHIS PPQ

Geographical Distribution

Xystrocera globosa originates from southeast Asia and is widely distributed in the Oriental Region (Bangladesh, India, Pakistan, Indonesia, Sri Lanka, Myanmar, Thailand, Laos, Malaysia, Philippines, Seychelles). It has spread to Oceania (Australia, New Guinea, Hawaiian Islands), Madagascan Region (Madagascar, Rodriguez, Mauritius), Caribbean (Puerto Rico), and subtropical areas of the Palaearctic Region (Israel, Egypt, Japan, Korea, Taiwan).

Host Plants

The beetle is polyphagous developing in plants assigned to four families, Mimosaceae, Papilonaceae, Malvaceae and Rosaceae. Host genera include: *Acrocarpus, Adenanthera, Adina, Albizzia, Bauhinia, Cassia, Duabanga, Haematoxylon, Parkia, Xylia, Paraserianthes, Samanea, Grewia, Salmalia* and *Prunus* (Masumoto *et al*., 1996, 2000; Friedman *et al*., 2008).

Description

Adult *X. globosa* beetles vary in size from 5 to 8 cm long, and are attracted to dying, freshly cut or recently-killed trees where they lay eggs on the bark of the green wood. They have prominent antennae, often as long or longer than their bodies. Their bodies are elongate, brown in colour and have distinctive longitudinal banding (Figs 6.2.1 and 6.2.3).

The larvae that emerge from the eggs, are wormlike, white to yellowish in colour with a brown head, round-bodied and deeply wrinkled (Fig. 6.2.2). They burrow into the tree and spend one to three years tunnelling through the wood. The tunnels may be just under the bark or in the heartwood, and are packed with coarse sawdust.

Biology

Adult *X. globosa* beetles emerge year-round from infested trees or material. After emergence they mate, and the females lay their eggs in cone-shaped holes or protected sites. The young larvae feed on the inner bark of the tree, then bore into the sapwood or heartwood. The mature larva makes a chamber for pupation. *Xystrocera globosa* may overwinter as a larva, pupa, or adult.

Xystrocera globosa infest dead, dying or highly stressed or weakened trees. Seasoned timber is also susceptible to borer infestation. They have the potential to have more than one generation per year but typically take two to three years for just one generation.

Dispersal and Detection

There appears to be no published data on the natural dispersal of *X. globosa*. The adults can fly but it is likely to be limited to short to medium distances. However, the immature stages of this beetle can be transported within wood products, and this is the primary route of entry into new geographical areas with the larvae infesting wooden products and/or wood packaging material used to secure commodities (i.e., pallets, crates, and dunnage). A common occurrence is for adult beetles to emerge from newly constructed log homes/furniture, however the beetles are unlikely to re-infest the building or furniture.

Economic and other Impacts

There appears to be little published information on the economic or environmental impact of *X. globosa*. However, it can damage wild and cultivated leguminous trees. The wood from the monkey pod tree is used for a variety of purposes depending on the location, ranging from construction purposes to fine furniture. Therefore, there is the potential for this beetle to affect monkey pod tree production and/or the commercial use of the wood.

6.3 Polyphagous Shot Hole Borer

Order: Coleoptera
Family: Curculionidae: Scolytinae
Species: *Euwallacea whitfordiodendrus* Schedl

	Present l	Threat		
	Absent ¡	Bio	Hlth	Econ
Ang	¡	ü		ü
Ber	¡	ü		ü
BVI	¡	ü		ü
Cay	¡	ü		ü
Mon	¡	ü		ü
TCI	¡	ü		ü

Figure 6.3.1 Life stages of a female polyphagous shot hole borer (*Euwallacea whitfordiodendrus*) from left to right: Young larva, older larva, pupa, immature adult, mature adult. © Akif Eskalen, University of California Riverside

Background

The Polyphagous Shot Hole Borer (PSHB), *Euwallacea whitfordiodendrus*, is an exotic ambrosia beetle. The “ambrosia” name refers to a symbiosis between the beetle and the two fungi that is carries: *Fusarium euwallaceae* and *Graphium* sp. The fungus is grown in beetle galleries/tunnels which have been created by the beetle as it bores into the tree, the female lays her eggs here and both the adults and emerging larvae then feed on the fungus. The fungi however cause a disease called Fusarium Dieback which interrupts the transport of water and nutrients in over 100 tree species. Once the beetle/fungal complex has killed the host tree, pregnant females fly off in search of a new host, carrying the fungus in special organs in her mouth parts.

The Polyphagous Shot Hole Borer is an invasive beetle that was first detected in California in 2003. It has the potential to threaten all the UKOTs native woody trees and shrubs due to its polyphagous nature.

Geographical Distribution

The Polyphagous Shot Hole Borer beetle is native to Vietnam and possibly elsewhere in South East Asia (Leathers, 2015). It has since been introduced to southern California, USA and Israel and is also listed as present in South Africa (Leathers, 2015; Paap *et al*., 2018). However, because PSHB is morphologically identical to *E. fornicatus* (the Tea Shot Hole Borer) the full distribution of PSHB in other regions of the world remains highly uncertain.

Figure 6.3.2 Female Polyphagous Shot Hole Borer © Stacy Hishinuma, UC Davis, Department of Entomology

Figure 6.3.3 Cross section of a tree infested with Polyphagous Shot Hole Borer. The branching tunnels made by the beetle weaken the structure of the tree © Akif Eskalen, University of California Riverside

Figure 6.3.4 Polyphagous Shot Hole Borer eggs are very tiny, oval shaped, and whitish. These eggs are seen within a cross-sectioned gallery © Akif Eskalen, University of California Riverside

Figure 6.3.5 The dark stains in the sapwood of this tree were caused by the fungus associated with the Polyphagous Shot Hole Borer which not only causes the beetle's galleries to be stained black, but also moves into the tree's xylem, clogging it © Akif Eskalen, University of California Riverside

Host Plants

Polyphagous Shot Hole Borer is a highly polyphagous species and has been recorded on a great number of woody trees and shrubs (Eskalen *et al*., 2013). Families with the most infected species are the Sapindaceae (maples), Fabaceae (legumes – only woody hosts) and Fagaceae (beeches, oaks), though reports of attacks on conifers are very limited. Colonisation by *F. euwallaceae* does not always occur following attack by PSHB or the fungus may colonise the tree, but the beetle may not successfully breed (Eskalen *et al*., 2013). Either of these outcomes, and an outcome of fungal colonisation and successful breeding of PSHB, can prove damaging to the tree (Fig. 6.3.3), but, in general, reproductive hosts suffer the most severe decline symptoms due to significant colonisation by *F. euwallaceae* and repeated attacks by adult beetles.

Description

Adult females are black in colour and 1.8-2.5 mm long (Fig. 6.3.2). Adult males are brown and smaller than the females at 1.5 mm long. More females are produced than males, which are flightless and very rarely leave the galleries. Mature siblings mate with each other so that females are already pregnant when they leave to start their own galleries. The eggs are off-white, partly translucent and approximately 0.3 mm long (Fig. 6.3.4). Eggs hatch in four to six days. Fertilized, diploid eggs (those with both maternal and paternal genetic information) hatch into females, while the unfertilized, haploid eggs (those with only maternal genetic information) hatch into males. There is usually only a single male egg per family. Larvae are white and legless (Fig. 6.3.1) and feed entirely on the symbiotic ambrosia fungus. The larval stage is complete in 16-18 days. Pupae are white and the same size as adult beetles (Fig. 6.3.1). The haploid pupa of the male is distinctly smaller than the pupa of the female. All the immature stages are restricted to the galleries in the xylem of the tree. Pupation takes place inside the same communal gallery as larval development. Adults emerge within seven to nine days.

Biology

The Polyphagous Shot Hole Borer is thought to complete two to four generations a year, but additional data is required to verify the life cycle. Female beetles initiate attacks on hosts and excavate branching galleries in the wood. The female introduces their ambrosial fungi to the galleries during construction, where it is the food source for both the adults and developing larvae. While in the galleries, female offspring mate with their flightless brothers, referred to as sibling mating. They then leave the galleries to look for locations to start new galleries, often in the same tree (EPPO, 2016; Mendel *et al*., 2012).

Dispersal and Detection

Natural spread of the PSHB beetle is likely to be rather limited (only the females fly) and the fungus, *F. euwallaceae,* is transferred into its host by the beetle. It is not known how these organisms have been introduced into California and Israel, but the transport and trade of infested plant material is a likely means of long distance dispersal e.g. on plants for planting, wood and wood packaging material (EPPO, 2016). In Israel, nearly all infestation reports came from commercial avocado production. Traps with lures have been used in commercial Californian avocado production to assess the spread and severity of the beetle although vigilant visual inspection is recommended.

Economic and other Impacts

In general, the largest economic impacts have been seen in avocado production in Israel and the US, where PSHB is now described as a serious threat to the industry. Typical symptoms of infestation in avocado include wilting of branches, breakages in stems and branches where beetle galleries are present, and death of trees – seen in both young and mature trees (Mendel *et al.*, 2012).

In California, PSHB has been found primarily in urban landscapes, but in February 2013 it was reported as present in the Angeles National Forest (Coleman *et al.*, 2013). Given the very recent introduction of this pest into the wider environment, no environmental impacts have been reported, but since it is known to breed and kill native Californian species these impacts may increase in the future. A Californian risk assessment concluded that significant environmental impacts are expected including changes to ecosystem processes (Leathers, 2015). There are no reported environmental impacts in Israel. However, it is the fungus *Fusarium euwallaceae*, which the beetle propagates, and its associated Fusarium Dieback disease that has the most critical impact.

6.7 Sri Lankan Weevil

Order: Coleoptera
Family: Cucurlionidae
Species: *Myllocerus undecimpustulatus undatus* Marshall

	Present l / Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	l			
Mon	¡			ü
TCI	¡			ü

Figure 6.4.1 Sri Lankan weevil, *Myllocerus undecimpustulatus undatus* adult © Gary R. McClellan

Background

Sri Lankan weevil, *Myllocerus undecimpustulatus undatus,* is a polyphagous plant pest native to Sri Lanka. It is also sometimes known as 'Yellow-headed ravenous weevil' or 'Asian grey weevil'. It has spread into India and Pakistan where it is reported to be among the most serious of all weevil pests in the region, attacking 20 different types of crop including cotton, vegetables, palms, and ornamentals. In the Americas, it was first detected in 2000 (possibly 1995) on *Citrus* sp. in Florida, USA, and spread rapidly through the county (Thomas, 2005). It was first detected in the Caribbean in the Cayman Islands in 2016. It is not known how it was introduced to the territory, but it may have been transported with turf grass and ornamentals imported from Florida for landscaping. Sri Lankan weevil poses an economic and environmental plant health risk to all the UKOTs in the Caribbean.

Geographical Distribution

Sri Lankan weevil is native to Sri Lanka and has spread through the Indian subcontinent and been introduced to North America and the Caribbean, where it has only been recorded from the Cayman Islands.

Host Plants

Sri Lankan weevil adults are polyphagous feeding on the foliage and flowers (Figs 6.4.2-6.4.3) of more than 150 plant species including native, ornamental, vegetable and fruit species. The adults exhibit a preference for Fabaceae. However, there is relatively little information available on the larval host plants, but adult beetles have been caught in Florida emerging from the soil beneath mango (*Mangifera indica*), lychee (*Litchi chinensis*), longan (*Dimocarpus longan*) and mamey sapote (*Pouteria sapota*) trees. In the laboratory, larvae have been successfully reared on pepper (*Capsicum* spp.), eggplant (*Solanum melongena*), carrot (*Daucus carota*) and sweet potato (*Ipomoea batatas*).

Figure 6.4.2 Adult Sri Lankan weevil feeding damage on *Terminalia catappa* © Susan Halbert, FDACS - Division of Plant Industry

Figure 6.4.3 Sri Lankan weevil adults on *Bauhinia blakeana* © Anita Neal, University of Florida

Figure 6.4.4 Foreleg femur bidentate © C. Malumphy

Figure 6.4.5 Hind femur tridentate © C. Malumphy

Figure 6.4.6 Elytra wider than thorax © C. Malumphy

Figure 6.4.7 Angled humeri © C. Malumphy

Figure 6.4.8 Head/thorax profile © C. Malumphy

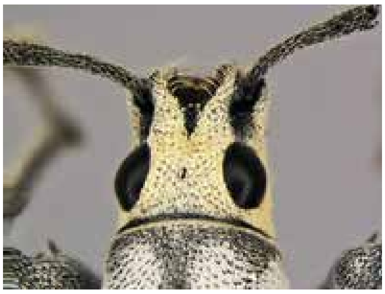

Figure 6.4.9 Yellow head © C. Malumphy

Figure 6.4.10 Life cycle of the Sri Lankan weevil: eggs, larva, pupa, and adult © Holly Glenn, Uni. of Florida

Description

Adult Sri Lankan weevils are mostly white with dark-mottling on the wing cases (Figs 6.4.1 and 6.4.3) and a pale yellowish head (Figs 6.4.1, 6.4.8 and 6.4.9). They vary in length from 6.0 to 8.5 mm, with the females being larger than the males. Diagnostic characters include the toothed femora (Figs 6.4.4-6.4.5), humeri (shoulders on the anterior edge of the wing cases) are broader than the prothorax (Fig. 6.4.6) and strongly angled (Fig. 6.4.7). There are eight described and several undescribed whitish weevils in the Caribbean in the genus *Atripus* which could be confused with Sri Lankan weevil. The Little leaf notcher, *A. floridanus,* is probably the most similar in appearance but can be distinguished by the femora which lack teeth, the humeri are not angled, and the elytra are greyish to white, with smaller black marks formed by perforations on the elytra (Mannion *et al*., 2006). Neal (2013) and O'Brien *et al*. (2006) provide detailed descriptions and illustrations to aid identification. The eggs (Fig. 6.4.10) are ovoid, less than 0.5 mm in length, white or cream-coloured at first, gradually turning brown when they are close to hatching. They are laid in clusters of three to five. The larvae (Fig. 6.4.10) are beige-white with a reddish-brown head, legless, C-shaped and up to 4 mm long. The pupae are cream coloured and darken with maturity.

Biology

Sri Lankan weevils are sexually reproductive, and each female may lay up to 360 eggs over 24 days directly on organic material at the soil surface. There are four larval instars which burrow into the soil and feed on plant roots for approximately one to two months. The larvae pupate in the soil for approximately one week. In the laboratory, the life cycle is completed in less than two months so there can be several generations each year if the climate is suitable.

Dispersal and Detection

Adults may crawl short distances over the host plant or fly to locate a new host. Long distance dispersal is likely to be due to anthropogenic activities, for example, larvae and pupae may be moved in plant trade in the soil of potted plants and the adults may hitch-hike with host plants and non-host materials. Adults are active during the day and relatively conspicuous (Figs 6.4.1 and 6.4.10) but if they detect your presence they feign death and drop to the ground. The first visible evidence of the weevil’s presence is usually the characteristic feeding damage to the foliage or flowers (Figs 6.4.2-6.4.3). The adult beetles chew inwards from the leaf margins causing leaf notching (other weevils cause similar damage). The damage is most noticeable when plants are producing new foliage and high populations of the weevil may cause almost complete defoliation. Intense feeding may cause plant decline or stunting, or even mortality of young seedlings. With healthy plants however, the feeding damage is likely to be cosmetic and the plants will recover. The larvae feed on the roots and are often overlooked until the host plant is showing signs of wilting and poor growth.

Economic and other Impacts

Leaf-feeding adults damage the foliage of ornamental plants, fruit trees, and vegetables, whereas the larvae injure root systems. Due to its feeding habits, the Sri Lankan weevil could negatively affect subtropical and tropical fruit, ornamental, and vegetable industries. In Florida, the potential economic impact to the horticulture industry in nurseries, landscape services, and horticultural retailers has been estimated to reach billions of dollars. Botanical gardens have reported damage and require control measures. The weevil could also have an environmental impact due to its adaptability to new hosts although there is insufficient information to assess the potential impact.

6.5 Red Palm Weevil

Order: Coleoptera
Family: Curculionidae
Species: *Rhynchophorus ferrugineus* Olivier

	Present l / Absent ¡	Threat Bio	Threat Hlth	Threat Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.5.1 Red palm weevil adult intercepted in the UK on a gourd imported from Sri Lanka © Fera

Background

Rhynchophorus ferrugineus is a highly invasive pest of palms that can have a significant economic, environmental and social impact when introduced into new geographical areas (EPPO, 2008). It is the most important pest of date palm (*Phoenix dactylifera*) in the world and a serious pest of coconut (*Cocos nucifera*). It is native to southern Asia and Melanesia but since the 1980s it has rapidly expanded its geographical range westwards. It has spread widely in the Middle East and Mediterranean region where the two main palm species of concern are date palm and Canary Island date palm (*Pheonix canariensis*), the main crop and ornamental species. It also attacks several other ornamental palms. It has devastated ornamental palms in many areas of the Mediterranean, changing the landscape.

Rhynchophorus ferrugineus has recently been introduced into the Caribbean and presents a potentially serious plant health threat to palms in all the UKOTs in the region (Roda *et al*., 2011).

Figure 6.5.2 *Rhynchophorus ferrugineus* distribution map © CABI

Figure 6.5.3 Red palm weevil larva © Luigi Barraco

Figure 6.5.4 Red palm weevil pupa © Luigi Barraco

Figure 6.5.5 Red palm weevil cocoon, consisting of tightly woven fibres, removed from the base of a dead palm, China © C. Malumphy

Figure 6.5.6 Red palm weevil adult on an adult hand to indicate the size of the beetle, China © C. Malumphy

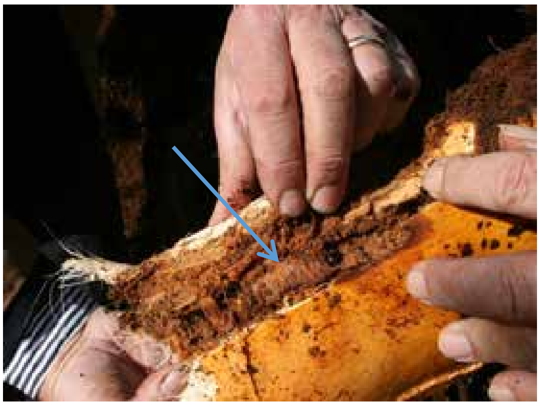

Figure 6.5.7 Red palm weevil larva, Italy © G. Pesapane - NPPO Campania region

Figure 6.5.8 Palm with a broken apex, Italy © R. Griffo - NPPO Campania region

Geographical Distribution

Rhynchophorus ferrugineus is present in the following regions and countries (Fig. 6.5.2): **Europe and Mediterranean**: Albania, Algeria, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Jordan, Libya, Malta, Morocco, Palestinian Authority Territories, Portugal, Slovenia, Spain, Tunisia and Turkey. It may also be more widespread in North Africa. **Asia**: Bahrain, Bangladesh, Cambodia, China, Georgia, India, Indonesia, Iran, Iraq, Japan, Jordan, Kuwait, Laos, Lebanon, Malaysia, Myanmar, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Sri Lanka, Syria, Taiwan, Thailand, United Arab Emirates, Vietnam and Yemen. **Caribbean**: Aruba, Curaçao and Netherlands Antilles. **Oceania**: Australia, Papua New Guinea, Solomon Islands, Vanuatu, Western Samoa (CABI/EPPO, 2016).

Figure 6.5.9 Dying and dead Canary Island date palms, Greece © C. Malumphy

Figure 6.5.10 Red palm weevil adult emerging from cocoon, killed by an entomopathogenic fungus, China © C. Malumphy

Figure 6.5.11 Dying Canary Island date palm, Montenegro © C. Malumphy

Figure 6.5.12 Dead and infested palms in a park, Italy © C. Malumphy

Figure 6.5.13 Pheromone trap for monitoring red palm weevil © C. Malumphy

Host Plants

Rhynchophorus ferrugineus feeds primarily on palms (Arecaeae) although it has occasionally been found feeding on non-palm hosts such as sugar cane (*Saccharum officinarum*) (EPPO, 2008). Palm hosts include betel nut palm (*Areca catechu*), Queen palm (*Arecastrum romanzoffianum*), sugar palm (*Arenga saccharifera*), sugar palm (*A. pinnata*), toddy palm (*Borassus flabellifer*), palmyra palm (*Borassus* sp.), Mexican blue palm (*Brahea armata*), pindo palm (*Butia capitata*), rattan (*Calamus merrillii*), fishtail palm (*Caryota cumingii*), giant mountain fishtail palm (*C. maxima*), dwarf fan palm (*Chamaerops humilis*), coconut (*Cocos nucifera*), gebang palm (*Corypha utan*), talipot palm (*C. umbraculifer*), oil palm (*Elaeis guineensis*), Kentia palm (*Howea forsteriana*), Chilean wine palm (*Jubaea chilensis*), cabbage tree palm (*Livistona australis*), ribbon fan palm (*L. decipiens*), Chinese fan palm (*L. chinensis*), Serdang palm (*L. saribus*), *L. subglobosa*, sago palm (*Metroxylon sagu*), *Oneosperma horrida*, nibong palm (*O. tigillarium*), Canary Island date palm (*Phoenix canariensis*), date palm (*P. dactylifera*), Indian date palm (*P. sylvestris*), Cretan date palm (*P. theophrasti*), royal palm (*Roystona regia*, synonym *Oreodoxa regia*), pygmy date palm (*Sabal umbraculifera*), round-leaf fountain palm (*Saribus rotundifolia*), Chusan palm (*Trachycarpus fortunei*) and *Washingtonia spp.*

Description

Adults are large, about 35 mm long and 10 mm wide, although they can be up to 42 mm long and 16 mm wide (Figs. 6.5.1 and 6.5.6), with a long rostrum (an elongate projection from the front of the head), characteristic for the weevils (EPPO, 2008). They are reddish-brown in colour with variable dark markings on the pronotum (section of the body behind the head). Eggs are whitish-yellow, smooth, shiny, cylindrical with rounded ends and slightly narrower at the anterior. Eggs are approximately 3 mm long and 1 mm wide. Larvae (Fig. 6.5.3) are legless, with a creamy-white body and brown hard head capsule, and grow up to 50 mm in length. The wing cases, legs and other appendages can be seen on the pupa (Fig. 6.5.4). Pupation occurs in an elongate oval, cylindrical cocoon made of fibrous strands, about 40 mm in length (Fig. 6.5.5). The cocoons are remarkably tough.

Biology

All life stages may be spent inside the host palm (EPPO, 2008). Each adult female deposit between 200 to 300 eggs in separate holes or cavities on the host plant. Eggs hatch in two to five days, and larvae bore into the interior of the palms (Fig. 6.5.7), feeding on the soft succulent tissues, discarding all fibrous material. The larval period ranges from 36-78 days (average 55 days) depending on temperature and host species. Pupation occurs in a fibrous cocoon and the adult weevils (Fig. 6.5.6) emerge 2-3 weeks after pupation. Hence the life cycle is completed in about 4 months.

Dispersal and Detection

It is very difficult to detect *R. ferrugineus* in the early stages of infestation (EPPO, 2008). Generally, it is detected only after the palm has been severely damaged. Early symptoms of attack include egg laying notches; cocoons inserted into the base of the palms; an eccentric growing crown; holes at the base of cut palms; symptoms resembling those caused by lack of water such as wilting, desiccation and necrosis of the foliage; tunnelling within the stems and trunk. Larvae and adults destroy the interior of the palm tree, often without the plant showing signs of deterioration unless damage is severe. Hollowing out of the trunk reduces its mechanical resistance, making the plant susceptible to collapse (Figs 6.5.8 and 6.5.11). In most cases, attack on *Phoenix* and other palms leads to the death of trees whatever their size (Figs 6.5.9, 6.5.11 and 6.5.12). Visual examination allows detection of symptoms but cannot determine if there are larvae and adults present inside the trunk. Pheromone traps (Fig. 6.5.13), acoustic detection or infrared systems can be used to detect this pest.

Economic and other Impacts

Rhynchophorus ferrugineus is a major economic pest of coconut palm, date palm, oil palm, sago palm and a range of ornamental palms (EPPO, 2008). Severely attacked plants exhibit a total loss of foliage and rotting of the trunk, which eventually results in the death of the tree. It has proved to be a devastating pest in many parts of the Mediterranean where large numbers of mature palms in urban areas and parks have had to be removed because infested palms may collapse and are a danger to the public. It can also have a detrimental social impact in areas such as the Middle East where the date palm is closely associated with culture and religion.

6.6 Agave Snout Weevil

Order: Coleoptera
Family: Curculionidae
Species: *Scyphophorus acupunctatus* Gyllenhal

	Present l / Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡	ü		ü
Ber	¡	ü		ü
BVI	l			
Cay	¡	ü		ü
Mon	¡	ü		ü
TCI	¡	ü		ü

Figure 6.6.1 *Scyphophorus acupunctatus* adult © Fera

Background

Scyphophorus acupunctatus, commonly known as the Agave snout weevil, Agave weevil, Sisal weevil or Yucca weevil, is a highly invasive species with a broad host range attacking plants belonging to the Agavaceae and Dracaenaceae (EPPO, 2006) (Fig. 6.6.1). It is the most important pest of cultivated and native agaves and threatens endangered and endemic species, especially in the Caribbean region (Waring & Smith, 1986; O'Boyle *et al*., 2017).

Scyphophorus acupunctatus can cause significant damage to important crops, particularly those in plantations where genetic diversity is low (Dalton, 2005; Chamorro *et al.,* 2016). Agave decline, a fatal condition occurring in agaves, is associated with larval infestations of *S. acupunctatus*. The weevil creates conditions that cause agaves to die before they bloom or can be harvested (Fig. 6.6.3). In addition to causing mechanical damage and consuming stored resources, larvae may be involved in symbiotic relationships with microorganisms that break down plant tissues (Waring & Smith, 1986). The weevil has a high fecundity (Harris, 1936; Chamorro *et al.,* 2016) and few known natural enemies (CABI, 2017) so can spread rapidly in favourable conditions.

Scyphophorus acupunctatus has caused a catastrophic decline in the population of *Agave mission*um, a century plant endemic to the Virgin Islands. The beetle poses a threat to *Agave* plants throughout the Caribbean.

Geographical Distribution

Scyphophorus acupunctatus is native to Central America, the southwestern United States and Mexico, and has expanded its range to areas within the Caribbean, Africa, Asia, Australia, parts of Europe and Hawaii (CABI, 2017) (Fig. 6.6.2). *Scyphophorus acupunctatus* was first detected in Puerto Rico in 2009

(Setliff & Anderson, 2011). It is also present in the US Virgin Islands where it was detected on Saint Thomas in around 1994, Saint John in 2001 and Saint Croix in 2010 (Gibney, 2004; Chamorro *et al.*, 2016). Within the British Virgin Islands, it was first reported on Tortola from 2000 (Osborne, 2002; Gibney, 2004) and Guana (Valentine & Ivie, 2005). Its presence is also recorded in Anegada, Virgin Gorda, Great Thatch Island, Great Tobago and Prickly Pear Island (O'Boyle et al., 2017).

Figure 6.6.2 *Scyphophorus acupunctatus* distribution map © CABI

Figure 6.6.3 Dead *Agave missionum* plant, killed by *Scyphophorous acupunctatus* in Anegada, BVI © C. Malumphy

Figure 6.6.4 *Agave missionum* with wound in central spike made by *Scyphophorous acupunctatus* © C. Malumphy

Figure 6.6.5 Adult of *Scyphophorous acupunctatus* at base of *Agave missionum* leaves in Anegada, BVI © C. Malumphy

Figure 6.6.6 *Agave missionum* with tunnel in central spike made by adult *Scyphophorous acupunctatus* © C. Malumphy

Host Plants

Scyphophorus acupunctatus is a specialist insect attacking plants belonging to the Agavaceae and Dracaenaceae (EPPO, 2006). It attacks many different species of *Agave* e.g. sisal (*A. sisalana*) and henequen (*A. fourcroydes*) used for fibre production, tequila (*A. tequilana*) used for beverages, century plant (*A. americana*) for ornamental purposes and species of *Beaucarnea*, Mexican grass tree (*Dasylirion longissimum*), dragon tree (*Dracaena draco*), *Furcraea*, Spanish bayonet (*Yucca aloifolia*), spineless Yucca (*Y. elephantipes*), great plains Yucca (*Y. glauca*), ornamental *Yucca* spp., and tuberose (*Polianthes tuberosa*) (EPPO, 2006; Walker 2008a).

Description

The lifecycle of the beetle has four stages: egg, larva, pupa, and adult described by Harris (1936). The eggs are small (1.6-1.75 mm in length and 0.7 mm in width), ovoid and creamy-white. The fully developed larvae are about 18 mm long, rotund, creamy-white, and legless with dark heads. The pupae are 15-19 mm in length and are pale yellow at first but darken as the black pigment of the developing weevil becomes visible through the cuticle. The adult weevils are dull brown to black, have a distinct downward curved long snout and are between 10-19 mm long (Fig. 6.6.1).

Biology

Details of the biology of *S. acupunctatus* are provided by Harris (1936). Adults seek new plant hosts, often a mature plant close to setting flower, and chew their way into the base of the plant, accessing through the space between the leaf attachments in order to lay their eggs (Figs 6.6.4-5). Eggs are laid in batches of 2-6 in the base of young bulbils or suckers, or in the hole made by the adult weevil in the central shoot of a larger plant. After hatching the larvae begin to feed on the plant tissues, forming tunnels (Fig. 6.6.6). The eggs and larvae only survive if there is a certain amount of moisture. The larvae eat the heart and damage the root system of the plant; by the time the damage is noticeable, it is often too late. Pupation takes place within a cocoon made of plant fibres and debris. The adult female takes a minimum of 25 days after emerging to reach sexual maturity with mating taking place predominantly on the bottom of the leaves or inside the agave head (Ruiz-Montiel *et al.*, 2008). The adult life span and reproductive capacity is not known, but a study has shown that three females averaged 62 eggs each over a period of three months (Harris, 1936).

The species breeds all year round with the lifecycle taking about 50-90 days to complete with up to four generations per year. The number of larval instars, and the timings of each developmental stage, varies with host plant species, larval nutrition and environmental conditions such as humidity and temperature; larvae and pupae develop most rapidly during the rains (Harris, 1936; Valdes-Estrada *et al.,* 2010). The beetle is cryptic in nature with all the life stages occurring within the host plant and the adult weevils emerging to infest new plants (Figueroa-Castro *et al*., 2016). The adults feed on the same plants as the larvae and are found in the roots, lower leaves, and inside the heads, especially on plants already in the process of putrefaction.

Dispersal and Detection

Plants for planting has been deemed the most likely dispersal mechanism (Perry, 2004). Adult beetles are transported in the international trade (including with non-host plants) from areas where *S. acupunctatus* occurs. Beetles may also be transported within the private movement of plants in the Caribbean region (O'Boyle *et al.,* 2017). The Caribbean islands rely on international tourism and the increased movement of people and cargo make 'hitch-hiking' of insects on planes, ships or in baggage potential routes of entry into the islands (Procter & Fleming, 1999).

Adult weevils are active fliers and are believed to be able to travel short distances when assisted by winds (Perry, 2004). No data on maximum flight distances have been found, but members of the subfamily Dryophthorinae will typically not fly further than 1km (Netherlands Plant Protection Service, 2009).

Infestations can be detected by examination of the leaves of *Agave*, *Furcraea* and *Yucca* plants (CABI, 2017). Holes 1 cm in diameter are indicative of adult emergence. Six or seven leaves on the same plant similarly affected is typically the result of adult feeding. Stems and leaf bases of young or weakened *Agave*, *Furcraea* and *Yucca* plants can be cut open to detect adults and larvae. Larvae can be specifically searched for by cutting open the stem base as they bore into the tender, subterranean tissues. Leaves of large, healthy sisal plants, when the heart of the central shoot is exposed, may show areas of brown, dried out epidermis approximately 20 cm from the base, and discoloration of the fibres.

Typical symptoms of *Scyphophorus acupunctatus* attack are also provided by Harris (1936). With advanced infestation the outer leaves lay close to the ground while the centre rosette of leaves stays upright, leaving a gap in between. Some of these species are so drought tolerant and the damage can occur so quickly, that the plant topples over from a severing of the root system before any other noticeable damage is apparent. Less severe infestations can show as a wrinkling of the base of lower leaves which does not respond to additional water (in drought conditions). Suckers that have been too deeply planted may begin to rot at the base and weevils are then attracted to them as secondary pests. Weevil attack on healthy leaves that are too strong to penetrate, produces a mottled area of dead epidermis approximately 20 cm from the leaf base; this damage is only distinguishable from that caused by friction because it occurs before the leaf has unfolded.

Traps lured with synthetic aggregation insect pheromone and food attractants have been shown to be efficient in trapping migrant adults, with the majority of those caught being female (Figueroa-Castro *et al*., 2016).

Economic and other Impacts

Scyphophorus acupunctatus has been a major problem in the tequila and henequen industries of Mexico (Woodruff & Pierce, 1973); the sisal industry of Africa and Indonesia (Clinton & Peregrine, 1963); and in the nursery and landscaping businesses of the south-western United States (Pott, 1976). Yield losses of 40% of henequen have been reported in Mexico (Ramirez, 1984) with significant economic damage (up to 70%) of commercial Agaves (Chamorro *et al.,* 2016).

The environmental impact posed by *S. acupunctatus* in the British Virgin Islands is very large as it threatens the endangered endemic species *Agave missionum* (O'Boyle *et al.*, 2017). There is also potential for the pest to have wider detrimental impacts on ecosystems and local people. *Yucca aloifolia* has been introduced to the Caribbean as its high tolerances for salt, drought and wind make it suitable for planting to prevent coastal erosion (Brown & Cooprider, 2012). *Yucca elephantipes* was introduced into Puerto Rico and Saint Croix as an ornamental, for its vitamin C-rich inflorescences eaten as a vegetable and for its leaves which produce a fibre used in construction (Morton & Dowling, 1991).

6.7 Mango Seed Weevil

Order: Coleoptera
Family: Curculionidae
Species: *Sternochetus mangiferae* (Fabricius)

	Present l Absent ¡	Threat Bio	Threat Hlth	Threat Econ
Ang	¡			ü
Ber	¡			ü
BVI	l			
Cay	¡			ü
Mon	l			
TCI	¡			ü

Figure 6.7.1 Adult *Sternochetus mangiferae* on a mango fruit © Crown copyright

Background

The mango seed weevil, *Sternochetus mangiferae* (Fig. 6.7.1), is an important monophagous pest of mangoes that seriously limits mango production and is widespread in most mango-growing countries. It is spread mainly by infested fruits because the weevil develops within the mango seed and can be transported unnoticed from one locality to another. Infestation symptoms are most obvious within the seed where the weevil largely completes its life cycle (Fig. 6.7.3). Here all life stages of the insect (larvae, pupae and adult), can be found. Externally the affected fruits appear normal, but very often are rotting from inside (Fig. 6.7.4). It is a quarantine pest in many countries and its presence in export mango can lead to shipments being rejected.

The mango seed weevil poses a significant plant health risk to all the UKOTs in the Caribbean.

Geographical Distribution

Sternochetus mangiferae is native to India but has been widely dispersed by commerce and is now widespread in Africa, Asia, Australia and islands of the Caribbean and the Pacific (OEPP/EPPO 2011; CABI, 2017) (Fig. 6.7.2).

Host Plants

Complete development of *S. mangiferae* is only achieved on mango (*Mangifera indica*) (CABI, 2017).

Description

The eggs are elongate, creamy white and surrounded by a protective brown covering with two tiny tails at one end, about 0.8 mm long and 0.3 mm wide (Woodruff & Fasulo, 2015). The newly emerged larva is an elongated, slender grub, white and legless (about 1.4 mm long). Older instars are compact, C-shaped and up to 18 mm long and 9 mm wide (Fig. 6.7.4) (Woodruff & Fasulo, 2015). The pupae are initially white but change to a very pale red colour just before eclosion and are 7.0-10.0 mm long and 6.0-8.0 mm wide (CABI, 2017). The adults are about 8 mm long and 4 mm wide (Figs 6.7.1 and 6.7.6). They are a short, compact weevil typical of the subfamily Cryptorhynchinae. When disturbed, the legs are compressed to the body, and the rostrum or beak fits snugly into a ventral groove. They are black, and covered with black, greyish or yellowish scales although the colour pattern can vary, depending partially on age (CABI, 2017; Woodruff & Fasulo, 2015).

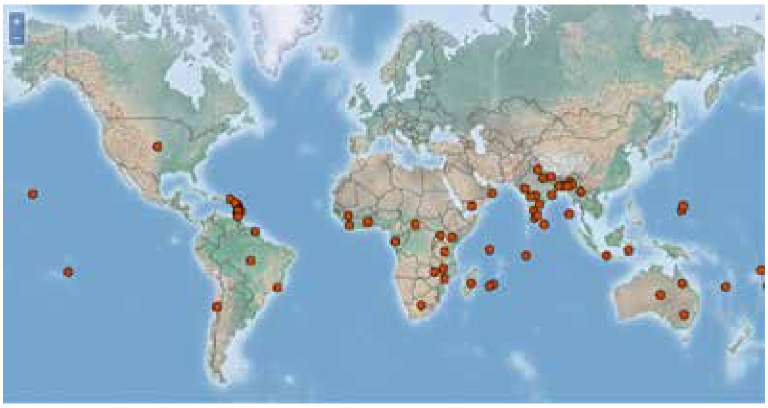

Figure 6.7.2 *Sternochetus mangiferae* distribution map © CABI

Figure 6.7.3 Mango fruit and seed cut in half to reveal a *Sternochetus mangiferae* larva © Crown copyright

Figure 6.7.4 Mango fruit rotting due to an infestation by *Sternochetus mangiferae* © Lesley Ingram, Bugwood.org

Figure 6.7.5 *Sternochetus mangiferae* adult emerging from inside a mango seed © Crown copyright

Figure 6.7.6 *Sternochetus mangiferae* adult newly emerged from a mango fruit imported from India © Crown copyright

Biology

Adult *S. mangiferae* feed on the leaves and tender shoots of mangoes during March and April in India (CABI, 2017). They are nocturnal, fly readily and usually feed, mate and oviposit from late afternoon to dusk. After emergence, adults enter a diapause which enables them to survive unfavourable conditions. The onset and termination of diapause appear to be associated with long-day and short-day photoperiod, respectively (Balock & Kozuma, 1964). During non-fruiting period, weevils diapause under loose bark on mango tree trunks and in branch terminals, or in crevices near mango trees (Balock & Kozuma, 1964). A few adults live through two seasons with a diapause period in between (CABI, 2017). Shukla and Tandon (1985) found that females began oviposition 3-4 days after mating when fruit was about marble-size. The oviposition period varies from 3 weeks to about 5 weeks (Shukla & Tandon, 1985). Females lay eggs singly on the skin or sometimes on the stems (Shukla & Tandon, 1985). Each female may lay 15 eggs per day, with a maximum of almost 300 over a 3-month period in the laboratory (Balock & Kozuma, 1964). Incubation requires 5-7 days (Balock & Kozuma, 1964). After hatching, the larva burrows through the flesh and into the seed. Complete larval and pupal development usually occurs entirely within the maturing seed (Balock & Kozuma, 1964). Upon maturation, the adults rapidly move out of the seeds (Fig. 6.7.5) and seek hiding places by crawling rather than flying. Often only one adult will mature in each seed, but as many as six have occasionally been recorded (Balock & Kozuma. 1964). Adults cut their way out of the naked seed, usually via a small circular hole, usually within a month or two after the fruit falls and decays. On rare occasions weevils may emerge from the seed before fruit fall and eat their way through the flesh of the ripe fruit, ruining it completely. Adults usually remain in the vicinity of the parent tree until the following fruiting season (CABI, 2017).

Dispersal and Detection

Natural spread of *S. mangiferae* is limited as the adults usually remain near their parent tree until the following fruiting season; high infestations appear year after year in some locations and low infestations appear in others (Balock & Kozuma, 1964). Long-range dispersal occurs largely through the transport of fruit and seeds containing larvae, pupae or adults. *Sternochetus mangiferae* has been intercepted in mango fruits and seeds in international trade (USDA, 1988). Mango plants may harbour diapausing adults.

Infested fruits are difficult to detect since there is usually no damage visible externally. Fruits should be examined with a pocket lens to look for the hardened, amber-coloured marks (often with two small angled tails at one end) attached to the site of oviposition, especially on the sinus of fruit. Mango seeds should be opened with a knife to reveal the immature or mature stages (larvae, pupae or adults. Infected fruits rot from the outer surface of the stones (Fig. 6.7.3) and may show holes, with the cotyledons turning black and forming a rotten mass which is visible when the stone is opened (OEPP/EPPO, 2011).

Economic and other Impacts

The economic impact of *S. mangiferae* is primarily due to it being a phytosanitary quarantine pest, restricting access to new foreign markets and contributing to rejections of fruit destined for existing export countries. In addition, mango seed weevil infestations can increase fruit drop during early fruit development and may reduce the germination capacity of seeds (Follett, 2002). Also, infestations significantly reduce fruit length and circumference in mango varieties Alphonso, Bombay Green and Raspuri (Abraham Verghese & Nagaraju, 2004).

6.8 Spotted Wing Drosophila

	Present l / Absent ¡	Threat: Bio	Threat: Hlth	Threat: Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Order: Diptera
Family: Drosophilidae
Species: *Drosophila suzukii* (Matsumura)

Figure 6.8.1 *Drosophila suzukii* adult male © Fera

Background

Drosophila suzukii is an Asian species of vinegar fly with a wide host range. In the past decade it has invaded North America, South America and Europe. Most species of *Drosophila* are secondary pests, their larvae only developing in previously damaged or rotting fruit. The biology of *D. suzukii*, however, is unusual in that the female can oviposit directly into healthy ripening fruit, still attached to the plant, and so the larvae can cause primary damage to soft-skinned fruit crops. The pest has spread rapidly in Europe and North America due to global trade and the initial lack of regulation over the spread of any *Drosophila species and* is a serious economic threat to soft summer fruit such as cherry, berry and peach crops. *Drosophila suzukii* has a high reproductive rate and short generation time; it can have up to 13 generations per year.

Geographical Distribution

Drosophila suzukii is native to eastern and south-eastern Asia, including China, Japan and Korea. Since the first find outside Asia in 1980 in Hawaii, the fly has rapidly expanded its geographical range. In 2008 it reached North America and is currently present in Canada, USA and Mexico. It simultaneously reached Spain and Italy in 2008 and is believed to be established throughout Europe (EPPO, 2017). It was first recorded in South America in 2013 (southern Brazil) and has since spread to Argentina, Chile and Uruguay (Andreazza *et al.*, 2017) (Fig. 6.8.2). Reports of the pest in Costa Rica in the late 1990's have been unproven.

Figure 6.8.2 *Drosophila suzukii* distribution map © CABI

Figure 6.8.3 *Drosophila suzukii* adult male (left) and female (right) © Fera

Figure 6.8.4 *Drosophila suzukii* oviposition puncture in a cherry © Fera

Figure 6.8.5 *Drosophila suzukii* larval feeding damage and eggs © Fera

Figure 6.8.6 *Drosophila suzukii* larva. © Frank A. Hale, University of Tennessee, Bugwood.org

Host Plants

Drosophila suzukii is a polyphagous pest infesting a wide range of soft fruit crops and many wild fruits. Major hosts include: dogwood (*Cornus kousa*), persimmon (*Diospyros*), Surinam cherry (*Eugenia uniflora*), strawberry (*Fragaria ananassa*), mulberry (*Morus* spp.), orange jasmine (*Murraya paniculata*), Chinese bayberry (*Myrica rubra*), *Prunus* spp. - sweet cherry (*P. avium*), plum (*P. domestica*), peach (*P. persica*), Asian pear (*Pyrus pyrifolia*), currants (*Ribes* spp.), *Rubus* spp. - Himalayan blackberry (*R. armeniacus*), loganberry (*R. loganobaccus*), raspberry (*R. idaeus*), evergreen blackberry (*R. laciniatus*), marionberry (*R. ursinus*), *Vaccinium* spp. (blueberry, cranberry) and grape

(*Vitis vinifera*). In the neotropics it is also recorded attacking Cherry of the Rio Grande (*Eugenia involucrata*), strawberry guava (*Psidium cattleianum*) and common guava (*P. guajava*).

Several hard fruits may also be attacked if the skin is already broken: kiwi (*Actinidia* spp.), persimmon (*Diospyros kaki*), loquat (*Eriobotrya japonica*), fig (*Ficus carica*), tomato (*Solanum lycopersicum*), apple (*Malus domestica*) and pear (*Pyrus* spp.) (Mann & Stelinski, 2017).

Drosophila suzukii prefers to infest undamaged, ripening fruit. If there is no suitable fruit available, however, then it will attack damaged or deteriorating fruit.

Description

Drosophila suzukii adults are small (3–4 mm) yellowish-brown flies with red eyes, a pale brown or yellowish-brown thorax and black bands on the abdomen (Figs 6.8.1 and 6.8.3). The antennae are short and stubby with branched arista. Males have a distinguishing dark spot along the front edge of each wing. Females are larger than males and possess a large serrated ovipositor. There are many other species of *Drosophila* that could easily be confused with *D. suzukii* due to their spotted wings therefore, expert examination by a specialist is needed for positive identification.

The eggs are 0.4 to 0.6 mm long, oval, milky-white and with two filaments (spiracles) at one end. The larvae are milky-white and cylindrical with black mouthparts. The body is tapered anteriorly with elevated posterior spiracles. First instar larvae are approximately 0.07 mm in length and mature larvae up to 6 mm in length.

The pupae are spindle-shaped, reddish-brown and bear two stalks with small finger-like projections, 3.5 mm long and 1.2 mm wide.

Biology

The pest has a high reproductive potential. It has multiple generations per year (up to 13 in Japan and 10 in California), and under optimal conditions a single life cycle could be as short as 8-14 days. Females may lay up to 60 eggs per day and between 200-600 eggs in their lifetime. On average, each female lays 1-3 eggs per fruit, but many different females may lay eggs in the same fruit so up to 60-70 flies may eventually emerge from a single fruit. Adults are highly mobile (CABI, 2017).

Drosophila suzukii larvae (Fig. 6.8.6) cause damage by feeding on the pulp inside fruit and berries; very quickly the fruit begins to collapse around the feeding site (Fig. 6.8.5). The initial signs of attack are small scars or depressions on the fruit surface at the points where the females have used their specially adapted ovipositors to deposit their eggs into the fruit (Fig. 6.8.4). The oviposition scar exposes the fruit to secondary infection by fungal or bacterial pathogens and other insect pests, including other vinegar flies such as *D. melanogaster*, which may cause rotting.

Adults generally live 20-56 days, but under extended suboptimal cold conditions will overwinter, living for more than 200 days (Kanzawa, 1935). *Drosophila suzukii* has been reported to vector yeasts and bacteria (Hamby *et al.*, 2012).

Dispersal and Detection

Accidental dispersal through movement of infested host fruits is the main pathway of introduction for this pest. Its rapid worldwide spread is in part due to increasing global fresh fruit trade and the cryptic nature of larvae hidden inside fruit. Detection of larvae inside the fruits can be done by careful visual inspection under optical magnification or by immersion of fruit samples in sugar or salt solution. After crushing the fruit the larvae float to the surface of the solution after 10 minutes (BCMA, 2013).

The presence of adult *D. suzukii* in the field can be monitored by using traps baited with different attractants. Traps can be made cheaply from lidded plastic pots, punched with holes and filled with a bait solution to attract the flies, or traps specifically for *D. suzukii* can be purchased commercially (e.g. DROSO-TRAP and Drososan). Some trap designs include red or black colouration, and this will help increase captures, but the bait is the most important component of the trap for attracting the flies and encouraging them to enter the trap. Typical components of bait solutions include yeast, sugar, fruit purees, apple cider vinegar, wine, and ethanol. Pre-made commercial lures are available for *D. suzukii*. Traps can be used for early detection in potentially newly-invaded areas, such as near fruit markets, warehouses of food retailers and sites where rotten fruits are disposed of (Cabi, 2017).

Economic and other Impacts

Drosophila suzukii is a polyphagous pest infesting a wide range of soft fruit hosts, including several economically important crops. Damage to fruit crops is frequently high and may reach 100% loss of unprotected fruits. The damaged fruits are considered unmarketable and economic impacts include reduced production, the cost of control, eradication, surveillance, sanitation, post-harvest sorting and significantly, lost export markets. In addition to economic losses, the global spreading of *D. suzukii* may have high social and environmental costs. Excessive use of insecticides has wide ranging environment and human health risks and chemical control can result in the rejection of fruits for export and consumption due to insecticide residues (Haviland & Beers, 2012).

The economic impact of *D. suzukii* has been studied in the United States (Bolda *et al.*, 2010), Switzerland (Mazzi *et al.*, 2017) and in Italy (De Ros et al., 2015; Ioriatti et al., 2012). In the Italian region of Trentino, the overall economic impact of *D. suzukii* on the production of *F. ananassa*, *Vaccinium* sp. (blueberries), *Rubus* spp. (raspberry and blackberry) and *P. avium* in 2010 was estimated at 3–4 million EUR. In 2008 economic losses (based on maximum reported yield losses) for California, Oregon and Washington were estimated at 40% for *Vaccinium* sp. (blueberries), 50% for caneberries, 33% for *P. avium* and 20% for *F. ananassa*. Production in these three states could sustain US$ 511 million in damages annually because of *D. suzukii* (Bolda *et al.*, 2010). In Brazil, the spread of *D. suzukii* is predicted to result in serious economic losses, approximately US$ 30 million for peach and fig production (Benito *et al.*, 2016).

6.9 Carambola Fruit Fly

Order: Diptera
Family: Tephritidae
Species: *Bactrocera carambolae* Drew & Hancock

	Present l Absent ¡	Threat Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.9.1 Pinned adult *Bactrocera carambolae* © Natasha Wright, Cook's Pest Control, Bugwood.org

Background

Bactrocera carambolae, commonly called the carambola fruit fly, is one of the most important Tephritidae pests in its native Asia. It is a polyphagous species that feeds on more than 100 host plants, including several species of economic importance, such as *Persea americana*, *Psidium guajava*, *Citrus* spp., *Mangifera indica*, and *Carica papaya* among others. As it is a highly invasive species, with a high dispersal potential and wide host range, it presents a potentially serious plant health threat to all the UK Overseas Territories with tropical climates, particularly to those located in the Caribbean where the fly has the potential to establish. It is a member of the *Bactrocera dorsalis* species complex (Oriental fruit fly species complex), a group of 85 morphologically similar species, many with overlapping host preferences. The most similar major pest species include *B. dorsalis*, *B. caryeae*, *B. kandiensis*, *B. occipitalis* and *B. pyrifoliae*.

Geographical Distribution

Bactrocera carambolae is native to southern Thailand, Peninsular Malaysia, Singapore, Borneo, Indonesia and Andaman Islands (India). It was introduced to South America in 1975 (Suriname) through small-scale trade of fruits from Indonesia, and in the subsequent years, spread to French Guyana (1989), Guyana (1994) and the state of Amapa, Brazil (1996) where it is considered A2 quarantine pest (CABI, 2017; Marchioro, 2016) (Fig. 6.9.2). It was successfully eradicated from Guyana in 2001 (EPPO, 2014).

There have been no invasive populations of *B. carambolae* or any other species in the Oriental fruit fly complex in the Caribbean.

Figure 6.9.2 *Bactrocera carambolae* distribution map © CABI

Figure 6.9.3 Adult female reared from carambola fruit from Malaysia © Fera

Figure 6.9.4 Caribbean fruit fly, *Anastrepha suspensa*, for comparison © Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org

Figure 6.9.5 Oriental fruit fly, *Bactrocera dorsalis*, larvae tunnelling in a mango © Fera

Figure 6.9.6 Carambola fruit with fruit fly oviposition punctures © USDA

Host Plants

In its native range *B. carambolae* attacks a wide range of fruits from 20 plant families, particularly carambola (*Averrhoa carambola*). Other major host species of economic importance include avocado (*Persea americana*), cashew nut (*Anacardium occidentale*), pawpaw (*Carica papaya*), *Citrus* spp., mangosteen (*Garcinia mangostana*), mangrove (*Rhizophora*), kumquat (*Fortunella margarita*), pomegranate (*Punica granatum*), rose apples (*Syzygium* spp.), spanish cherry (*Mimusops elengi*) and strawberry guava (*Psidium cattleianum*) (CABI, 2017).

In Brazil it predominantly attacks *A. carambola* and guava (*Psidium guajava*), but also feeds on native South American fruit such as, abiu (*Pouteria caimito* and *P. macrophylla*), araza (*Eugenia stipitata*), Barbados cherry (*Malighia emarginata*), cocoplum (*Chrysobalanus icaco*), Malay apple (*Syzygium malaccense*), mango (*Mangifera indica*), peppers (*Capsicum* spp.), sapodilla (*Manilkara zapota*), wild sugar-apple (*Rollinia mucosa*) and yellow mombin (*Spondias mombin*) (Lemos *et al.*, 2014). In Suriname it attacks 20 species of wild and cultivated hosts, predominantly South American species. Major hosts in order of preference are: carambola (*A. carambola*), curacao apple (*Syzygium samarangense*), West Indian cherry (*Malpighia punicifolia*), mango (*Mangifera indica*), guava (*Psidium guajava*), malay apple (*Syzygium malaccense*), and tropical almond (*Terminalia catappa*) (Sauers Muller, 2005).

Description

Carambola fruit fly is a member of the *B. dorsalis* species complex, which can be distinguished as follows: The adults of the Oriental Fruit Fly (OFF) complex are distinctively different to the indigenous Caribbean fruit fly (*Anastrepha suspensa*) (Fig. 6.9.4). They are relatively smaller, with a body length of about 8mm and the body colour has variable dark markings, much darker than *A. suspensa.* The thorax has dark-brown to black markings and lateral yellow markings and a yellow scutellum (Figs 6.9.1 and 6.9.3). The abdomen has two horizontal black stripes and a longitudinal median stripe extending from the base of the third segment to the apex of the abdomen, which may form a T-shaped pattern. The ovipositor is very slender and sharply pointed. OFF's have wings with clear membranes, except for a narrow costal band, whereas the Caribbean fruit fly has distinctively patterned wings.

Identification to species level requires morphological examination of adult flies and is incredibly difficult. Species in the OFF complex are morphologically very similar, and some species exhibit great variability, therefore it is essential that they are examined by an experienced entomologist. Rapid and *accurate* diagnostics are critical to prevent the establishment and limit the spread of invasive fruit flies.

Third instar larvae are creamy-white to pale yellow in colour, around 10 mm long, sub-cylindrical, with the front-end pointed and the rear-end broad (Fig. 6.9.5). The small tapering head has two heavily sclerotised mouth hooks, 8-11 oral ridges with accessory plates, and paired prominent anterior spiracles with 9-15 tubules. The posterior spiracles are positioned at the rear of the body and are a very useful taxonomic character at family level. The spiracles have 3 sub-parallel slits and are not present on raised lobes. Pupae are cylindrical, approximately 4.9 mm long and yellow- reddish brown (White & Elson-Harris, 1994).

It is generally difficult and not reliable to morphologically identify eggs, larvae or pupae to species level or to the *Bactrocera dorsalis* complex.

Biology

No specific details on the biology of *B. carambolae* are available, it is assumed to be similar to that of *B. dorsalis*. All fruit flies have six developmental stages: egg, three larval instars, pupa and adult. Each adult female OFF usually lay around 1200-1500 eggs over their 1-3-month lifespan. Up to 20 eggs are laid under the skins of fruit that are just beginning to ripen, sometimes where the skin is already broken. The eggs hatch within 1-3 days (although this can be delayed up to 20 days in cool conditions), and the larvae develop inside the fruit. Larvae tunnel and feed in the fruit for 6 to 35 days (usually depending on temperature and food availability). The larvae exit the fruit by making a small hole and fall to the ground and pupate in soil. Depending on temperature, adult emergence occurs after 10-12 days under ideal conditions, but up to 90 days in cool conditions (CABI, 2017)

Dispersal and Detection

Carambola fruit fly is a highly invasive pest with a high dispersal potential, primarily through the movement of fruit with trade. After introduction, it can easily establish because it has a high reproductive potential and high biotic potential (short life cycle, up to 10 generations of offspring per year depending on temperature) (based on the biology of *B. dorsalis*). There is limited reliable data on the flight and passive wind-assisted dispersal of this species. The spread of the pest in South America has been comparatively slow, perhaps limited by the level of commercial fruit production in Suriname where it first established (Sauers Muller, 2005). Recent studies using climatic modelling do indicate that *B. carambolae* has potential to spread to other regions of the world where habitat is favourable, and certain areas in the Caribbean (Marchioro, 2016). Climatically suitable areas were predicted in Central and South America, the Caribbean, Sub-Saharan Africa and Southeast Asia.

The major risk of introduction is from the import of fruit containing larvae, either as part of cargo or through the smuggling of fruit in airline passenger baggage or mail. For example, in New Zealand Baker and Cowley (1991) recorded 7-33 interceptions of fruit flies per year in cargo and 10-28 per year in passenger baggage.

Fruit flies can be detected as eggs or larvae in fruits, or as adults caught in traps. Attacked fruit will often have puncture marks made by the female fly's ovipositor (Fig. 6.9.5). Fruit with a high sugar content may exude globules of sugar. A depression and discolouration may occur at the puncture site. Eggs or larvae may be found by carefully cutting into the fruit. It is necessary to rear them to adulthood for species identification. Pupae may be found beneath the soil at the base of the host plant or in any packaging associated with imported fruit. A variety of specialist traps are available for trapping adult flies. Males are attracted to the chemical pheromone Methyl Eugenol. Many countries that are free of *Bactrocera* spp., e.g. the USA (California and Florida) and New Zealand, maintain a grid of methyl eugenol and cue lure traps, at least in high-risk areas (ports and airports) if not around the entire climatically suitable area. The trap used will usually be modelled on the Steiner trap or Jackson trap.

Economic and other Impacts

The Carambola fruit fly is a polyphagous species that feeds on more than 100 host plants, including several species of economic importance, such as *P. americana*, *A. occidentale*, *P. guajava*, *Citrus* spp., *M. indica*, and *C. papaya* among others. Damage to fruit crops is frequently high and may reach 100% loss of unprotected fruits. Economic impacts include reduced production, the cost of eradication and surveillance, and significantly, lost export markets through quarantine restrictions. The array of control methods includes insecticide sprays to foliage and soil, bait-sprays, male annihilation techniques, releases of parasitoids and sterilized flies, and cultural controls such as bagging fruit and improved sanitation. In Brazil, the spread of Carambola fruit fly is predicted to result in serious economic losses, US$ 30.7 million in the first year, and approximately US$ 92.4 million after the third year of infestation. The production of *A. occidentale* is considered at highest risk, with almost 90% of its production area within the suitable predicted range of *B. carambolae*, followed by *C. papaya* (78%), *Citrus tangerina* (51%), *P. guajava* (38%), *Citrus limon* (30%), *Citrus sinensis* (29%), *M. indica* (24%) and *P. americana* (20%) (Marchioro, 2016). In addition to economic losses, the global spreading of *B. carambolae* may have high social and environmental costs. Excessive use of insecticides has wide ranging environment and human health risks.

6.10 Oriental Fruit Fly

Order: Diptera
Family: Tephritidae
Species: *Bactrocera dorsalis* (Hendel)

	Present l / Absent ¡	Threat: Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.10.1 Adult male *Bactrocera dorsalis* reared from guava exported from Sri Lanka © Fera

Background

Bactrocera dorsalis, commonly called the Oriental Fruit Fly (OFF), is the most important pest Tephritid in its native Asia. As it is a highly invasive species with a high dispersal potential and an extensive host range, it presents a potentially serious plant health threat to all the UK Overseas Territories with tropical climates, particularly to those located in the Caribbean where the fly has the potential to establish. It is a member of the *Bactrocera dorsalis* species complex (OFF species complex), a group of 85 morphologically similar species, many with overlapping host preferences. The most similar major pest species include *B. carambolae*, *B. caryeae*, *B. kandiensis*, *B. occipitalis* and *B. pyrifoliae*.

Geographical Distribution

Native to parts of the Indian subcontinent, China and southeast Asia, *B. dorsalis* is now found in at least 65 countries, including parts of America and Oceania, and most of continental Africa (sub-Saharan countries) (Fig. 6.10.2) (CABI, 2017). It is well established in the Pacific Islands of Hawaii and French Polynesia, and most countries of sub-Saharan Africa have become infested since the first appearance (as *Bactrocera invadens,* now considered a subjective synonym of *B. dorsalis sensu latu*) in Kenya in 2003. It has also been introduced to Madagascar, the Comoros and Cape Verde Islands, and has successfully been eradicated from Mauritius. There are frequent detections of OFF in North America (California and Florida) and an ongoing eradication programme in California since August 2017. The distributions of other notable pest species in the OFF complex are mapped with their pest status and invasion history by Vargas *et al.* (2015).

There have been no invasive populations of the OFF complex in the Caribbean.

Figure 6.10.2 *Bactrocera dorsalis* distribution map © CABI

Figure 6.10.3 Caribbean fruit fly, *Anastrepha suspensa*, for comparison © Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org

Figure 6.10.4 *Bactrocera dorsalis* larva and emergence hole in guava (*Psidium guajava*) fruit © Fera

Figure 6.10.5 Oriental fruit fly, *Bactrocera dorsalis*, larvae tunnelling in a mango (*Mangifera indica*) © Fera

Figure 6.10.6 Rotting mango (*Mangifera indica*) fruit imported from the Philippines heavily infested with *Bactrocera dorsalis* larvae © Fera

Host Plants

Bactrocera dorsalis is a highly polyphagous species whose larvae develop in a very wide range of wild and cultivated host fruits. It attacks over 270 host species in 50 plant families; host relationships vary from region to region and are dependent largely on what fruits are available.

Important hosts for the Caribbean region include apple (*Malus pumila*), banana (*Musa paradisiaca*), coffee (*Coffea* spp.), fig (*Ficus carica*), guava (*Psidium guajava*), loquat (*Eriobotrya japonica*), mango

(*Mangifera indica*), orange (*Citrus sinensis*), paradise tree (*Simarouba glauca*), pawpaw (*Carica papaya*), peach (*Prunus persica*), peppers (*Capsicum* spp.), plum (*Prunus domestica*), *Pyrus* spp., red mombin (*Spondia purpurea*), soursop (*Annona squamosa*), star fruit (*Averrhoa carambola)*, strawberry-guava (*Psidium cattleianum*) and tomato (*Solanum lycopersicum*).

Due to confusion between *B. dorsalis* and related species in South East Asia, some published host data may concern other species within the *B. dorsalis* species complex.

Description

The adults of the OFF complex are distinctively different to the indigenous Caribbean Fruit Fly (*Anastrepha suspensa*) (Fig. 6.10.3). They are relatively smaller, with a body length of about 8mm and the body colour has variable dark markings (Fig. 6.10.1), much darker than *A. suspensa.* The thorax has dark-brown to black markings and lateral yellow markings and a yellow scutellum. The abdomen has two horizontal black stripes and a longitudinal median stripe extending from the base of the third segment to the apex of the abdomen, which may form a T-shaped pattern. The ovipositor is very slender and sharply pointed. Oriental fruit flies have wings with clear membranes, except for a narrow costal band, whereas the Caribbean Fruit Fly has distinctively patterned wings.

Identification to species level requires morphological examination of adult flies and is incredibly difficult. Species in the OFF complex are morphologically very similar, and some species exhibit great variability, therefore it is essential that they are examined by an experienced entomologist. Rapid and *accurate* diagnostics are critical to prevent the establishment and limit the spread of invasive fruit flies.

The larva of the Oriental fruit fly is quite like that of the Mediterranean fruit fly (*Ceratitis capitata*). Third instar larvae are creamy-white to pale yellow in colour, around 10 mm long, sub-cylindrical, with the front-end pointed and the rear-end broad (Fig. 6.10.5). The small tapering head has two heavily sclerotised mouth hooks, 9-11 oral ridges with accessory plates, and paired anterior spiracles with 9-12 tubules. The posterior spiracles are positioned at the rear of the body and are a very useful taxonomic character at family level. The spiracles have 3 sub-parallel slits and are not present on raised lobes. Tephritidae pupae are cylindrical, approximately 4.9 mm long and yellow-reddish brown.

It is not possible to morphologically identify eggs, larvae or pupae to species level or to the *Bactrocera dorsalis* complex.

Biology

All fruit flies have six developmental stages: egg, three larval instars, pupa and adult. Each adult female Oriental fruit fly usually lays around 1200-1500 eggs over their 1-3-month lifespan. Up to 20 eggs are laid under the skins of fruit that is just beginning to ripen, sometimes where the skin is already broken. The eggs hatch within 1-3 days (although this can be delayed up to 20 days in cool conditions), and the larvae develop inside the fruit. Larvae tunnel and feed in the fruit for 6 to 35 days (usually depending on temperature and food availability). The larvae exit the fruit by making a small hole (Fig. 6.10.4) and fall to the ground and pupate in soil. Depending on temperature, adult emergence occurs after 10-12 days under ideal conditions, but up to 90 days in cool conditions (CABI, 2017).

Dispersal and Detection

Oriental fruit fly is a highly invasive pest introduced to new areas in fruit trade and illegally in passenger baggage. After introduction, it can easily establish and disperse because it has a high reproductive potential and high biotic potential (short life cycle, up to 10 generations of offspring per year depending on temperature). There is limited reliable data on the flight and passive wind-assisted dispersal of this species (CABI, 2017).

An extensive host range and a tolerance of both natural and cultivated habitats over a comparatively wide temperature range has facilitated its success. The pest has spread rapidly across Africa since it was detected in 2003 in Kenya and is now reported from 36 other countries in the sub-Saharan region.

Fruit flies can be detected as eggs or larvae in fruits or as adults caught in traps. Attacked fruit will often have puncture marks made by the female fly's ovipositor. Fruit with a high sugar content may exude globules of sugar. A depression and discolouration may occur at the puncture site. Eggs or larvae may be found by carefully cutting into the fruit. It is necessary to rear them to adult for species identification. Pupae may also be found beneath the soil at the base of the host plant or in any packaging associated with imported fruit. A variety of specialist traps are available for trapping adult fruit flies. Male Oriental fruit fly are attracted to the chemical pheromone Methyl Eugenol, and both sexes can be monitored using sticky traps. Many countries that are free of *Bactrocera* spp., e.g. the USA (California and Florida) and New Zealand, maintain a grid of methyl eugenol and cue lure traps, at least in high-risk areas (ports and airports) if not around the entire climatically suitable area. The trap used will usually be modelled on the Steiner trap or Jackson trap.

Economic and other Impacts

Bactrocera dorsalis is an economically important pest in its native range and other parts of the world where it has accidentally spread. Increasing international tourism and trade, and changes in climate and land use facilitate the introduction of the pest. It is considered is one the most destructive fruit fly pests and remains at the top of quarantine lists. The highly polyphagous nature of the species enables it to attack a wide range of fruits, and damage to fruit crops is frequently high (Fig. 6.10.6) and may reach 100% loss of unprotected fruits. Economic impacts include reduced production, the cost of eradication and surveillance, and significantly, lost export markets through quarantine restrictions. In Mauritius, the total cost of the eradication operation was approximately US$ 1 million (Seewooruthun *et al.*, 2000). In California it has been estimated that the cost of not eradicating Oriental fruit fly would range from US$ 44 to 176 million in crop losses, additional pesticide use, and quarantine requirements. (CABI, 2017)

Invasive *B. dorsalis* is highly competitive with native fruit flies wherever it has established. In many African countries it has displaced the indigenous *Ceratitis cosyra* as the dominant mango pest and has proven to be more aggressive (Ekesi *et al.*, 2009). There is also potentially a significant environmental impact following the initiation of chemical control, which could harm native insects and species of conservation significance.

6.11 Mediterranean Fruit Fly

Order: Diptera
Family: Tephritidae
Species: *Ceratitis capitata* (Wiedemann)

	Present l Absent ¡	Threat Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.11.1 *Ceratitis capitata* adult male © Fera

Background

Ceratitis capitata, commonly called Medfly or Mediterranean fruit fly is one of the most serious invertebrate pests of citrus and many other fruits in most countries with a warm, Mediterranean, tropical or subtropical climate. It is a highly invasive species with a high dispersal potential and an extensive host range. It therefore presents a potentially serious plant health threat to all the UK Overseas Territories with tropical climates, particularly to those located in the Caribbean where the fly is currently expanding its geographical range.

Geographical Distribution

Native to sub-Saharan Africa, *C. capitata* is now widespread in Africa, and through accidental transport during trade has spread to other warm tropical and sub-tropical parts of the World including Mauritius, Reunion, Seychelles, North Africa, Southern Europe, the Middle East, Western Australia and to parts of Central, South and North America (Fig. 6.11.2). In the Caribbean, *C. capitata* is present only in Puerto Rico, this being a transient population under eradication (CABI, 2017). An outbreak in the Dominican Republic in 2015 was successfully eradicated in 2017. Previous reports of it being present in Jamaica and the Netherlands Antilles have proven unreliable following surveillance programmes (CABI, 2017).

Figure 6.11.2 *Ceratitis capitata* distribution map © CABI

Figure 6.11.3 *Ceratitis capitata* male orbital setae © Fera

Figure 6.11.4 *Ceratitis capitata* larva © Florida Division of Plant Industry, Florida

Figure 6.11.5 *Ceratitis capitata* pupae © Fera

Figure 6.11.6 Ugandan pepper with oviposition and larval exit holes made by *Ceratitis capitata* © Fera

Figure 6.11.7 *Ceratitis capitata* monitoring trap in *Citrus* orchard © Russell IPM

Figure 6.11.8 UK Plant Health Service inspectors examining imported fruit © Fera

Host Plants

Ceratitis capitata is a highly polyphagous species whose larvae develop in a very wide range of wild and cultivated host fruits, with a preference for tree fruit crops with thin skins. Host relationships vary from region to region and are dependent largely on which fruits are available.

Important hosts for the Caribbean region include apple (*Malus pumila*), avocado (*Persea americana*), calabur (*Muntingia calabura*), cashew (*Anacardium occidentale*), various *Citrus* spp., coffee (*Coffea* spp.), fig (*Ficus carica*), kiwifruit (*Actinidia deliciosa*), lychee *(Litchi* spp.), longan (*Dimocarpus longan*), loquat (*Eriobotrya japonica*), mamey sapote (*Pouteria sapota*), mango (*Mangifera indica*), medlar (*Mespilus germanica*), papaya (*Carica papaya*), pear (*Pyrus communis*), peppers (*Capsicum* spp.), *peach* (*Prunus persica*), guava (*Psidium guajava*), red mombin (*Spondia purpurea*), star-apple (*Chrysophyllum caimito*), strawberry-guava (*Psidium cattleianum*), tropical almond (*Terminalia catappa*), tuna/cactus fruit (*Opuntia* spp.) and white sapote (*Casimiroa edulis*) (White & Elson-Harris, 1994; Cabi, 2017).

Description

Medfly adults (Fig. 6.11.1) are easily recognisable by external morphology. They have a wing length of 3.6-5 mm, a scutellum that is black with a narrow wavy yellow band across the base, and a distinctive wing pattern with yellow crossbands and a costal band distinct from the discal crossband. Males have a pair of orbital setae modified with black diamond-shaped tips (Fig. 6.11.3). De Meyer (2000) provides a key for the separation of similar species.

Third instar larvae are creamy-white to pale yellow in colour, medium-sized (6.5-9.0 mm), sub-cylindrical, with the cephalic-end pointed and the caudal-end broad (Fig. 6.11.4). The small tapering head has two heavily sclerotised mouth hooks, 9-11 oral ridges, an absence of accessory plates and paired anterior spiracles with 9-12 tubules. The posterior spiracles are positioned at the rear of the body and are a very useful taxonomic character at family level. The spiracles have 3 sub-parallel slits and are not present on raised lobes. Steck & Ekesi (2015) provide a very detailed larval description.

Pupae are cylindrical, 4 to 4.3 mm long, yellow-reddish brown, and resemble a swollen grain of wheat (Fig. 6.11.5).

Biology

All fruit flies have six developmental stages: egg, three larval instars, pupa and adult. Each adult female Medfly usually lays around 300 eggs over their 2-3-month lifespan. Up to 10 eggs are laid under the skins of fruit that is just beginning to ripen, sometimes where the skin is already broken. The eggs hatch within 2-3 days, and the larvae develop inside the fruit. Larvae tunnel and feed in the fruit for 6 to 11 days (depending on temperature and food availability). The larvae exit the fruit by making a small hole (Fig 6.11.6) and fall to the ground and pupate in soil. Depending on temperature, adult emergence occurs after 6-13 days (White & Elson-Harris, 1994).

Dispersal and Detection

Medfly is a highly invasive pest with a very high dispersal potential, primarily through movement of fruit. Their very large host range, and a tolerance of both natural and cultivated habitats over a comparatively wide temperature range, has made them a successful invader in many tropical and subtropical parts of the World. A 1989 outbreak of medfly in California, USA is speculated as being caused by a deliberate act of bio-terrorism.

Fruit flies can be detected as eggs or larvae in fruits or as adults caught in traps (Fig. 6.11.7). Attacked fruit will often have puncture marks made by the female fly's ovipositor (Fig. 6.11.6). Fruit with a high sugar content may exude globules of sugar. A depression and discolouration may occur at the puncture site. Eggs or larvae may be found by carefully cutting into the fruit. It is necessary to rear them to adult for species identification. Pupae may also be found beneath the soil at the base of the host plant or in any packaging associated with imported fruit. A variety of specialist traps are available for trapping adult fruit flies. Male medflies are attracted to Tri-Med-Lure and both sexes can be monitored using BioLure or by sticky traps.

Economic and other Impacts

Ceratitis capitata is one of the World's most destructive fruit pests. It is an economically important pest in Africa and many other parts of the World where it has accidentally spread. Damage to fruit crops is frequently high and may reach 100% loss. It is the most damaging pest of citrus fruits in many areas it has invaded. Economic impacts include reduced production, the cost of eradication and surveillance, and lost export markets.

In the Dominican Republic, agriculture is the second most important industry and a major employer. An outbreak of Medfly in 2015 led to the United States banning the import of 18 host fruits, with an estimated US$ 42 million loss to the economy. In July 2017 the Dominican Republic was declared free of the pest following a thorough eradication programme using Sterile Insect Technique (Dominican Today, 2017).

6.12 Red Imported Fire Ant

Order: Hymenoptera
Family: Formicidae
Species: *Solenopsis invicta* Buren

	Present l Absent ¡	Threat Bio	Hlth	Econ
Ang	l			
Ber	¡	ü	ü	ü
BVI	l			
Cay	l			
Mon	l			
TCI	¡	ü	ü	ü

Figure 6.12.1 *Solenopsis invicta* adult red imported fire ant © Ryan Whitehouse and Joe A. MacGown

Background

The red imported fire ant, *Solenopsis invicta* (Fig. 6.12.1), also known as the fire ant or RIFA, is an aggressive omnivorous forager that occurs in high densities. *It* is highly invasive and destructive due to its high reproductive capacity, large colony size, ability to exploit human disturbances, wide food range and ability to sting (CABI, 2017). If disturbed, it can relocate quickly, ensuring survival of the colony.

Infestations can impact households, humans, livestock, crop production, flower/nursery production, infrastructure, wildlife, recreation, tourism and businesses. Worker ants respond rapidly and aggressively to disturbances and bite and sting repeatedly with a painful burning sting. *Solenopsis invicta* venom forms a white fluid-filled pustule or blister at the red sting site, a symptom characteristic only of fire ants (Fig. 6.12.2). *Solenopsis invicta* can also attack livestock and wildlife. They are attracted to mucous membranes in the animals' eyes and nostrils, and their stings cause blindness and swelling, which may cause suffocation. Immobilized animals, such as penned or new born livestock, are at greatest risk. *Solenopsis invicta* has become widespread in the Caribbean and as such poses a threat to all UKOTs in the Caribbean.

Geographical Distribution

Solenopsis invicta is native to tropical areas of Central and South America (CABI, 2017). It is an invasive pest that has become widespread in the southern USA and Caribbean (ISSG, 2014; Morrison *et al*., 2004). It has also spread to China, Malaysia, Singapore, Australia and New Zealand, although it has been successfully eradicated from New Zealand (CABI, 2017; Pascoe, 2001).

Figure 6.12.2 Reactions to stings from *Solenopsis invicta*, BVI © C. Malumphy

Figure 6.12.3 *Solenopsis invicta* – multiple life stages © Imported Fire Ant Station, USDA APHIS PPQ, Bugwood.org

Figure 6.12.4 Mound of *Solenopsis invicta*, BVI © C. Malumphy

Figure 6.12.5 Colony of *Solenopsis invicta*, BVI © C. Malumphy

Solenopsis invicta was first reported in Puerto Rico and the U.S. Virgin Islands around 1980 (Buren, 1982; Wetterer & Snelling, 2006). Between 1991 and 2001, the ant was recorded from Trinidad and Tobago, the Bahamas, the British Virgin Islands, Cayman Islands, Antigua, and the Turks and Caicos Islands (Davis *et al*., 2001; Deyrup *et al*., 1998; Wetterer, 2013). Since then, infestations have been discovered in Anguilla, Saint Martin, Barbuda, Montserrat, Saint Kitts, Nevis, Aruba, and Jamaica (Wetterer, 2013). Cold climates are unsuitable for the ant's successful establishment although it may survive in heated structures. It is estimated that continental areas receiving more than 510 mm of rainfall a year will support *S. invicta* whereas continental areas receiving less rainfall will only support populations near sources of permanent water or in regularly irrigated areas (Morrison *et al*., 2004).

Host Plants

Significant damage by fire ants can occur to crops grown in the Caribbean region, including soybean (*Glycine max*), citrus (*Citrus* spp.), eggplant (*Solanum melongena*), okra (*Abelmoschus esculentus*), sweet potato (*Ipomoea batatas*), cabbage (*Brassica* spp.), cucumber (*Cucumis sativus*), sunflower (*Helianthus* spp.) and watermelon (*Citrullus lanatus*) with ants feeding on the buds and fruits. The ants also feed on the branches, new terminal growth, flowers, young fruit, bark and sap of tree crops. *In citrus orchards, S. invicta* tunnels through roots and tubers, feeds on plants, fruit and seeds and can girdle young trees (Stewart & Vinson, 1991). As well as causing direct damage to plants, *S. invicta* also aggravates populations of other insect plant pests such as Hemiptera (e.g. aphids, scale insects and mealybugs), with the ants consuming the honeydew produced by these pests.

Description

The life cycle of the ant has four stages: egg, larva, pupa, and adult (Fig. 6.12.3). The eggs are spherical and creamy-white, and the larvae are legless, cream-coloured and grub-like with a distinct head capsule (CABI, 2017). The pupae resemble the worker ants and are initially creamy-white but turn darker before the adult ants emerge (Fig. 6.12.3). The eggs, larvae and pupae are referred to as a brood.

Worker ants are females and do the work of the colony, with larger individuals functioning as soldiers who defend the colony. Worker ants are wingless, dark reddish-brown with black abdomens, have a two-segmented antennal club and range from 1.5 to 5.0 mm long (Fig. 6.12.1). Workers in the genus *Solenopsis* are polymorphic, meaning they are physically differentiated into more than two different body-forms (Vinson, 1997). A new colony's first workers, called minims, are smaller than those of later generations. Minors are slightly larger, and medias larger still (Taber, 2000). The largest is the major worker, which (in later generations) can reach lengths of up to 5.0 mm (Taber, 2000).

At certain times of the year, winged males and queens are produced. The queen ants are reddish-brown and larger than the worker ants (9.0 mm), whereas the males are shiny and black with a smaller head.

Biology

A general overview of the biology and ecology of *S. invicta* can be found in Vinson (1997). *Solenopsis invicta* is a social insect with colonies producing hills, nests or mounds where they reside (Figs 6.12.4-6.12.5). *Solenopsis invicta* can live in a wide range of habitats and is able to dominate altered habitats. The mounds generally occur in open, sunny areas for purposes of brood thermoregulation (Porter & Tschinkel, 1993) and are especially common in disturbed and irrigated soil. The ant is also well adapted to opportunistic exploitation of disturbed habitats (Morrison *et al*., 2004). The colonies can occasionally occur indoors, within electrical equipment and tree trunks (Vinson, 1997). In disturbed and developed forested areas, *S. invicta* nests are abundant along roadsides and trails near buildings, but it is not abundant in densely wooded areas. Colonies also occur in lawns, gardens, school yards, parks, roadsides and golf courses. A fully developed colony can contain over 200,000 to 400,000 ants.

Mounds may reach 30 to 40 cm high and 30 to 50 cm in diameter in clay-type soils. The mounds have no entrance holes or central entrance hole on the surface, instead foraging worker ants enter and exit through tunnels radiating up to 5 to 10 m away from the mound. Inside, the mounds have interconnecting galleries that may extend 30 to 40 cm deep, although some tunnels can penetrate to the water table. The disturbance of mounds results in a rapid defensive response by the worker ants, which quickly run up the vertical surfaces to bite and sting any objects that are encountered. Under extremely hot, dry conditions, colonies may live underground and not develop surface nests or mounds.

Fire ants are omnivorous, but a large portion of their diet are invertebrates which they sting and kill (Holway *et al*., 2002; Ness & Bronstein, 2004). They also feed on dead animals, plant tissues, seeds, fruits and are attracted to honey dew and sap flows (Vinson, 1997). There are four larval instars which are fed only a liquid diet by the workers until they reach the third instar (Vinson, 1997). When the larvae reach the fourth instar, they can digest solid foods. Worker ants will bring solid food rich in protein and deposit it in a depression in front of the mouth of the larvae (Vinson, 1997). The larvae will secrete digestive enzymes that break down the solid food and regurgitate it back to worker ants.

The queen spends her life laying eggs. At certain times of the year, winged males and queens are produced that fly into the air, where they mate. The males die soon after wards and the mated queens form new colonies. Newly-mated *S. invicta* queens often move to pastures (Taber, 2000). The mated queens find suitable nesting sites, shed their wings, and begin digging underground chambers in which to lay eggs. The first eggs and larvae, which emerge as minims, are cared for by the queen. The workers then care for the queen and subsequent brood, forage for food, and expand the nest.

Dispersal and Detection

The spread of *S. invicta* has been aided by humans via the shipment of infested articles such as nursery potting media, sod, bales of hay and soil (CABI, 2017). Objects contaminated with soil pose a high risk *(CABI, 2017)*. Infestations recorded from Aruba and Jamaica have only been found on golf courses that import sod from Florida, indicating an important potential means of spread (Wetterer, 2013). Interspecific competition with resistant native ant fauna may limit its spread (Porter *et al*., 1997).

Electrical equipment e.g. air conditioning units, power company transformers, traffic signal control cabinets, electrical pumps and car electrical systems can also attract infestations seeking warmth and shelter, but also provide a means of spread (CABI, 2017).

Early detection by active surveillance followed by nest treatment is critical to any eradication attempt. Although expensive, it is nothing compared to the economic costs of permanent infestations. Pitfall traps and attractant baits are both methods that can yield good results (Stringer *et al.*, 2011). Fire ants are significantly more attracted to baits containing mixed proteins (hotdog or ground meat combined with sweet peanut butter) compared to sugar or water baits. Baited pitfall traps are better than non-baited pitfall traps and food baits at detecting incipient ant colonies, whereas food baits perform well when trying to detect large colonies (Stringer *et al.*, 2011).

Economic and other Impacts

Solenopsis invicta is a major pest to various economic sectors costing an estimated US$ 6 billion annually in the USA (Drees & Lard, 2006). Infestations can impact households, humans, livestock, crop production, flower/nursery production, infrastructure, wildlife, recreation, tourism and businesses. If not treated immediately, infestations of new areas by S. invicta are likely to be expensive or even impossible to eradicate. Infestations covering several hectares may cost thousands of US dollars to eradicate, whereas infestations covering several hundred hectares could cost tens of thousands of dollars to eradicate (Drees *et al*., 2002). In Hawaii it is estimated that the potential cost of *S. invicta* infestations could total US$ 2.5 billion over a 20-year period following introduction and minimal government response (Gutrich *et al*., 2007).

6.13 Formosan Subterranean Termite

Order: Isoptera
Family: Rhinotermitidae
Species: *Coptotermes formosanus* (Shiraki)

	Present l / Absent ¡	Threat Bio	Threat Hlth	Threat Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.13.1 Formosan Subterranean Termite worker (top), soldier (bottom). © Gerald J. Lenhard, Louisiana State University, Bugwood.org

Background

Formosan subterranean termites, *Coptotermes formosanus*, live in nests underground and, like other subterranean termites, feed on dead trees and wooden debris on the soil surface of natural habitats. Their nests are made up of soil, chewed wood or plant material, the termite's own saliva and their faecal matter – this substance is known as carton (Fig. 6.13.3). When in final form the nest can appear as a typical rocky structure due to the look of carton. Their nests can also be very large, housing hundreds and thousands of termites in a single colony. However, the termites require a moist environment and if moisture levels are not right underground they may build nests above ground e.g. on boats, porches, flat rooftops, trunks of trees both dead and alive, as well as walls of homes and buildings.

Coptotermes formosanus can cause structural damage to buildings (Fig. 6.13.5) and infrastructure and substantial economic losses. For this reason, along with its widespread global distribution, it is a threat to all the UKOTs in the Caribbean.

Geographical Distribution

Coptotermes formosanus is native to China in the Palearctic region and has since been introduced to many other regions of the world. *C. formosanus* was first reported to have been transported to Japan in the 1600's and later recorded to have infested Hawaii in the late 1800's, by the 1950's it was recorded in Africa. In 1960 it began to appear in the United States and by 2010 it had spread throughout the south-east region of this continent; it is also present in the U.S. Virgin Islands within the Caribbean (CABI, 2017).

Figure 6.13.2 Tree damage caused by *Coptotermes formosanus* © Wood Product Insect Lab USFS Gulfport, MS, Bugwood.org

Figure 6.13.3 *Coptotermes formosanus* carton nest © Wood Product Insect Lab USFS, Gulfport, MS, Bugwood.org

Figure 6.13.4 Damage to a nest of Formosan subterranean termites brings large numbers of workers and soldiers with dark, oval shaped heads scrambling to repair the hole © Scott Bauer, USDA Agricultural Research Service, Bugwood.org

Figure 6.13.5 Termite damage to a window sill. The nest was located two floors below in the soil. Much of the wood had been consumed before they were detected. © Scott Bauer, USDA Agricultural Research Service, Bugwood.org

Host Plants

Coptoformes formosanus is an opportunistic feeder of any material containing cellulose. A large number of living plants are known to be attacked by *C. formosanus*, but it usually does not kill the plants unless the root system is significantly damaged (Lai *et al.*, 1983; La Fage, 1987). Records show that living citrus (*Citrus* spp.), eucalyptus (*Eucalyptus* spp.) and sugar canes (*Saccharum* spp.) may be killed by *C. formosanus*, but in most cases damage occurs in the heartwood of a tree (Fig. 6.13.2). The infested trees may be more easily blown over by high winds due to the loss of structural strength. The pest status of *C. formosanus* is most significant when it attacks wood products in a house such as structural lumbers, cabinets, etc. *Coptoformes formosanus* is also known to damage non-cellulose materials in search of food, including plastic, concrete and soft metal (Suszkiw, 1998). Occasionally underground high-voltage power lines may be penetrated by *C. formosanus*, resulting in an area-wide power cut (CABI, 2017).

Description

The colonies of *C. formosanus* contain three primary castes: the reproductives, soldiers, and workers. The majority of the nestmates are workers that are responsible for the acquisition of nutrients, i.e. cellulose in the wood. The white soft-bodied workers are 4-5 mm long (Fig. 5 44.1). They are hard to distinguish from other termite species. The alates (winged reproductive termites) and soldiers are most useful for identification. The alates are yellowish-brown and 12-15 mm long. The alates are attracted to lights, so they are usually found near windows, light fixtures, windowsills and spider webs, around well-lit areas. The soldiers are approximately the same size as the workers and have an orange-brown oval-shaped head, curved mandibles and a whitish body (Fig. 6.13.1). When disturbed, the soldiers readily attack any approaching objects, and may secrete a white gluey defensive secretion from the frontal gland; they will also scramble to repair their nest (Fig. 6.13.4). Approximately 10-15% of a *C. formosanus* colony consists of soldiers (CABI, 2017).

Biology

A single colony of *C. formosanus* may produce over 70,000 alates. Swarming occurs at dusk on a humid and windless night. After a brief flight, alates shed their wings. Females immediately search for nesting sites with males following closely behind. When the pair finds a moist crevice with wooden materials, they form the royal chamber and the female lays approximately 15 to 30 eggs (depending on temperature). Within two to four weeks, young termites hatch from the eggs. The reproductives nurse the first group of young termites until they reach third instar. One to two months later, the queen lays the second batch of eggs which will eventually be nursed by termites from the first egg batch. It may take three to five years before a colony reaches a substantial number to cause severe damage and produce alates (Suszkiw, 1998).

Dispersal and Detection

Natural spread of *C. formosanus* occurs by the dispersal flights of the reproductives originating from mature colonies. However, *C. formosanus* is better known for its tendency to establish populations in new geographic areas via maritime vessels, cars, and by importation of infested materials such as in wood packaging, containers and the plant trade. It can take new colonies several years to reach a size that creates detectable damage, and they can often be mistaken for other subterranean termites, e.g. of the *Reticulitermes* genus.

Economic and other Impacts

Coptotermes formosanus can cause substantial economic losses. It is recognized as one of the most dangerous of all subterranean termites because of its widespread global distribution. In New Orleans (USA) the control and repair cost due to *C. formosanus* is estimated at US$ 300 million annually (Suszkiw, 1998; 2000). In 1998, the USDA initiated an eradication program in the French Quarter of New Orleans (Henderson, 2001; Ring *et al.*, 2002). Over the next 13 years over US$ 70 million dollars was spent on studies to control this termite and although termite numbers were reduced, eradication was not achieved. This termite is the single most economically important insect pest in Hawaii. It causes damage to underground electrical and phone lines by eating through PVC pipes and shorting-out electrical systems. Its preference for using clay may explain why clay-laden levees in New Orleans are so heavily infested (Henderson, 2008). It is one of the few termite species that will regularly infest creosoted rail road ties, wooden trestles and telephone poles.

6.14 Cactus Moth

Order: Lepidoptera
Family: Pyralidae
Species: *Cactoblastis cactorum* (Berg)

	Present l / Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	l			
Mon	l			
TCI	¡			ü

Figure 6.14.1 *Cactoblastis cactorum* caterpillars (left) and adult moth (right) ©USDA

Background

The cactus moth, Cactoblastis cactorum, is a voracious feeder of prickly pear (*Opuntia* spp.) and closely related species of cacti. It has been introduced in various locations around the world to provide biological control of invasive cacti species and has proved itself successful in Australia and some Caribbean islands. However, from the Caribbean it has spread into Florida and attacked non-target cacti species. It is feared that it will cause large scale losses of native cacti diversity in North America and possibly have a large economic, social and ecological impact in areas rich with Opuntia spp. in southwestern USA and Mexico.

The cactus moth was introduced to Montserrat in 1962 (Bennett *et al.*, 1985) as a biological control agent but has since gradually spread throughout the Caribbean Islands. *Cactoblastis cactorum* threatens native landscapes and agricultural industries. It is therefore a significant plant health risk to all the UKOTs with tropical climates wherever *Opuntia* spp. are present.

Geographical Distribution

Cactoblastis cactorum is native to South America but has been introduced into Africa, Asia, the Australasia-Pacific region and North America (Stiling, 2002). After its earlier success as a biocontrol agent in Australia and South Africa, it was introduced into the Caribbean in 1957 to manage weedy native cactus species. The moth gradually spread throughout the Caribbean Islands and was first detected in south Florida on Big Pine Key in 1989 (Bloem & Bloem, 2012).

Host Plants

Cactoblastis cactorum feeds on prickly pear cacti species (*Opuntia* spp.) and other related cacti of the subfamily Opuntioideae: Cactaceae (CABI, 2017).

Figure 6.14.2 *Cactoblastis cactorum* egg stick © University of Florida

Figure 6.14.3 *Cactoblastis cactorum* larvae live and feed communally inside the cacti pads © University of Florida

Figure 6.14.4 *Cactoblastis cactorum* larvae feeding damage: frass and oozing (left)*;* interior of the pads entirely eaten (right) © University of Florida

Figure 6.14.5 *Cactoblastis cactorum* caterpillars feeding on *Consolea rubescens*, BVI © C. Malumphy

Figure 6.14.6 Cactus *Consolea rubescens* killed by *Cactoblastis cactorum* infestation, BVI © C. Malumphy

Figure 6.14.7 *Cactoblastis cactorum* adult moth, © 2007 Jeff Hollenbeck

Description

Cactoblastis cactorum adults are fawn with faint dark dots and lines on their wings (Figs 6.14.1 and 6.14.7). It normally rests with its wings wrapped around its body (Fig. 6.14.1). The forewings are greyish brown but whiter toward the costal margin. Distinct black antemedial and subterminal lines are present. Hindwings are white, semihyaline at the base, smoky brown on the outer half with a dark line along the posterior margin. Females have a wingspan of 27-40 mm and males 23-32 mm. Larvae are gregarious in nature, initially pinkish-cream coloured, with black red dots on the back of each segment. Later instars become orange and the dots coalesce to become a dark band across each segment (Figs 6.14.1 and 6.14.5); they reach up to 1.5 cm in length. The pupa is enclosed in a fine white silk cocoon (CABI, 2017).

Biology

The female lays her eggs in the form of a chain, the first egg is attached to the end of a spine or spicule, and succeeding eggs (average 75, and up to 140) are stacked coin-like to form an egg-stick (Fig 6.14.2). The incubation period of eggs depends on temperature. The eggs usually hatch in 23-28 days. The larvae crawl from the egg-stick onto the cladode or pad and burrow into it, usually within a few centimetres of the oviposition site. The larvae feed gregariously moving from cladode to cladode as the food supply is exhausted (Fig. 6.14.3). During feeding the frass is pushed out of the pad and forms a noticeable heap (Fig. 6.14.4). Fully developed larvae usually leave the plant and spin white cocoons among debris of rotting cladodes, in the leaf litter, in crevices in the bark of nearby trees, under stones and logs, just beneath the surface of the soil and in similar protected niches. Pupation occasionally occurs in the cladode. The average length of the pupal period is 21-28 days. The moth emerges, and the cycle is repeated. Adults have no functional mouthparts and emerge only to reproduce. The average longevity of the adult is nine days (Zimmerman *et al.*, 2004).

Dispersal and Detection

Dispersal of *C. cactorum* to new locations can arise from its successful use as a biological control agent, by natural dispersal locally or from the nursery trade. The arrival of *C. cactorum* in the Florida Keys may have been the result of the moth naturally dispersing across the Caribbean, or it may have been introduced unintentionally on horticultural prickly pear cacti imported into Florida (Solis *et al.*, 2004). As the adult moths do not have the ability to fly long distances (Zimmerman *et al.*, 2004) it is probable that they hitch-hiked, were windblown or were imported in infested cacti.

Infestations of *C. cactorum* can usually highly conspicuous and easy to detect due to the severe damage caused (Figs. 6.14.3-6.14.6) and the presence of the brightly coloured larvae. Infested cactus pads will droop and fall to the ground and the whole plant collapse.

Economic and other Impacts

The feeding activities of *C. cactorum* larvae are capable of destroying entire stands of cacti. The species threatens native landscapes and agricultural industries (USDA APHIS 2005). There is substantial concern over the potential westward spread of *C. cactorum* to the western United States and Mexico where it could threaten more than 80 native *Opuntia* species and the economic resources (e.g., food, medicine, and emergency fodder) that they provide (Simonson *et al.*, 2005). *Opuntia* species are cultivated as a food product in Mexico, and they are major community components in some western U.S. ecosystems (Solis *et al.*, 2004).

6.15 Cotton Bollworm

Order: Lepidoptera
Family: Noctuidae
Species: *Helicoverpa armigera* (Hübner)

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.15.1 Cotton bollworm larva (left) and adult moth (right) © Crown copyright

Background

The cotton bollworm, *Helicoverpa armigera*, like its close relatives *H. zea* and *Heliothis virescens* in the New World, is a moth pest of major importance in most areas where it occurs, damaging a wide variety of food, fibre, oilseed, fodder and horticultural crops. Its considerable pest significance is based on the peculiarities of its biology - its mobility, polyphagy, rapid and high reproductive rate and diapause make it particularly well adapted to exploit transient habitats such as man-made ecosystems. Its predilection for the harvestable flowering parts of high-value crops including cotton (*Gossypium* spp.), tomato (*Solanum lycopersicum*), sweetcorn (*Zea mays*) and the pulses confers a high economic cost, and socio-economic cost in subsistence agriculture, due to its depredations. However, regional and even relatively local differences in host preference can give rise to differences in pest status on particular crops; this was shown by populations in northern and southern India where severe infestations of cotton are only a relatively recent event.

Helicoverpa armigera poses a significant economic plant health risk to all the UKOTs as it is one of the most important polyphagous and widely distributed pests in the world. It is listed as an A1 quarantine pest.

Geographical Distribution

Helicoverpa armigera is native to Europe and Asia but has recently extended its already considerable geographical range from Europe, Africa, Asia and Australasia to the New World. It was formally reported as present in Brazil and Paraguay in 2013 (Czepak *et al.*, 2013; EPPO 2014) and Argentina and Puerto Rico in 2014 (Murúa *et al.*, 2014; NAPPO, 2014), but given the extent of the area infested and high abundance it is likely to have been present in South America for some time before detection (Kriticos *et al.*, 2015).

Figure 6.15.2 *Helicoverpa armigera* larva damage on corn © Crown copyright

Figure 6.15.3 *Helicoverpa armigera* eggs © Crown copyright

Figure 6.15.4 *Helicoverpa armigera* larvae showing colour variation © Crown copyright

Figure 6.15.5 *Helicoverpa armigera* adult moth © Tony Davison

Host Plants

Helicoverpa armigera is highly polyphagous, feeding on about 200 plant species, mainly annuals, developing on a wide range of food, fibre, oil and fodder crops as well as on many wild plants and perennial horticultural crops. The most important crop hosts of which *H. armigera* is a major pest are cotton (*Gossypium* spp.), pigeon pea (*Cajanus cajan*), chickpea (*Cicer arietinum*), tomato (*Solanum lycopersicum*), sorghum (*Sorghum bicolor*) and cowpea (*Vigna unguiculata*) (CABI, 2017).

Description

The eggs are white to yellowish, brownish at hatching (Fig. 6.15.3). Young larvae are pale green but later instar larvae are very variable in colour (yellowish-green to dark brown) with a narrow, dark, median dorsal band on each side and are up to 40 mm long (Figs 6.15.1 and 6.15.4). The adults are stout bodied (Fig. 6.15.1), the forewings are yellowish to orange in females (Fig. 6.15.5) and greenish-grey in males, with a slightly darker transversal band in the distal third. The kidney-shaped marking is slightly distinct and smoky. The hind wings are pale grey with a broad, darker marginal band and a small, brown marking near the base, the wing span is 35-40 mm (Fig. 6.15.1). The antennae are covered with fine hairs (King, 1994).

Biology

Each female *H. armigera* can lay several hundred eggs, distributed on all parts of the plants, flowers and fruit included. At optimal temperature, the larvae can hatch after less than three days. They then pass through four instars over a period of three to four weeks. The caterpillars are rather aggressive, occasionally carnivorous and, when the opportunity arises, cannibalistic. If disturbed, they let themselves drop from the plant and roll up on the ground (USDA factsheet 2014).

The caterpillars are voracious and can feed on leaves and stems, but they show a strong preference for reproductive organs such as buds, inflorescences, berries, pods, capsules etc. They bore into these parts, leaving large, round holes. Older larvae often enter the plant tissue with the anterior part of their bodies only. Young instars, however, may disappear completely inside, so they are sometimes not discovered before the produce (e.g. tomatoes) is processed. They pupate inside a silken cocoon several centimetres deep in the soil. During this stage, they can overwinter if necessary in seasonal climates, but they cannot resist severe frost. Otherwise, pupation lasts about 2-3 weeks. Under favourable conditions, the whole development cycle can be completed in little more than a month, so numerous generations per season are possible, especially in warmer areas. In the tropics, reproduction continues throughout the year. The adult insects are good fliers and are mostly active at night. The duration of the adult stage depends upon the availability of food, temperature etc. but is usually about 3 weeks, with female moths generally living longer than males (CABI, 2017).

Dispersal and Detection

Adult *H. armigera* are capable of long distance migratory flights, largely governed by prevailing weather systems (Shimizu & Fujisaki, 2002; CABI, 2007). However, it is effectively a facultative migrant, not displaying typical migratory behaviour, but responding largely to local environmental cues. The success of the cotton bollworm is partly due to its well-developed survival strategies, diapause and dispersal, which enable it to exploit food sources separated both by unfavourable times and by distance and to escape its natural enemies.

Movement in international trade is also a major means of its dispersal, mainly on ornamental plants and on cut flowers but also in cotton bolls and in tomato fruits. This species was intercepted over 800 times at US ports of entry mainly in commodities meant for consumption (USDA factsheet, 2014).

Detection is obvious when the larvae are feeding on the surface of plants, but they are often hidden within the plant organs (flowers, fruits etc.). Bore holes and heaps of frass (excreta) may be visible, but otherwise it is necessary to cut open the plant organs to detect the pest.

Economic and other Impacts

Helicoverpa armigera is listed as an A1 quarantine pest, and the damage it causes, and control costs are annually estimated, world-wide, to exceed US$ 5 billion (Lammers and MacLeod, 2007) It is a major pest of cotton (*Gossypium* spp.), tomatoes (*S. lycopersicum*) and other solanaceous crops, legumes (such as peas and beans) and maize (*Z. mays*). Secondary infections by fungi and bacteria are very common and they lead to rotting of fruits. Injury to growing tips disturbs normal plant development; maturity may be delayed, and fruits are often dropped. For example, in cotton, attacked blooms will frequently open prematurely and stay fruitless; when the bolls are damaged, some will fall off, and those that remain either fail to produce lint entirely, or they produce lint of inferior quality. In all cases, the economic value of the crops, for commercial or for industrial use, is much reduced (CABI, 2017).

6.16 Fall Armyworm

Order: Lepidoptera
Family: Noctuidae
Species: *Spodoptera frugiperda* (Smith)

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	l			
Ber	l			
BVI	l			
Cay	l			
Mon	l			
TCI	¡			ü

Figure 6.16.1 *Spodoptera frugiperda* larva (left) and adult (right) © Fera

Background

The fall armyworm, *Spodoptera frugiperda*, is a lepidpopteran pest that feeds in large numbers on leaves and stems of more than 180 plant species, causing major damage to economically important cultivated grasses such as maize (*Zea mays*), rice (*Oryza* spp.), sorghum (*Sorghum bicolor*) and sugarcane (*Saccharum officinarum*) but also to other vegetable crops and cotton. It has been repeatedly intercepted at quarantine in Europe and was first reported from Africa in 2016 (Goergen *et al*., 2016) where it is causing significant damage to maize crops (Fig. 6.16.3) and has great potential for further spread and economic damage. The term "armyworm" can refer to several species, often describing the large-scale invasive behaviour of the species' larval stage.

Spodoptera frugiperda poses a significant economic plant health risk to all the UKOTs and is naturally present in all the Caribbean Islands (EPPO, 2014).

Geographical Distribution

Spodoptera frugiperda is native to tropical and subtropical regions of the Americas. In 2016 it was reported for the first time from the African continent and has now been confirmed in 28 African countries (Fig. 6.16.2) (CABI, 2017).

Host Plants

Spodoptera frugiperda is a polyphagous pest reported to infest 186 host plant species in North and Central America (Casmuz *et al.*, 2010). It exhibits a preference for wild and cultivated grasses, maize, rice, sorghum, millet and sugarcane (Poaceae). Other hosts from 27 families include *Allium* (Liliaceae), *Brassica* spp. (Brassicaceae), *Capsicum* and other Solanaceae including aubergine (*Solanum melongena*), potato (*S. tuberosum*) and tomato (*S. lycopersicum*), *Cucumis* (Cucurbitaceae), *Gossypium* (Malvaceae), *Phaseolus* (Fabaceae) and *Ipomoea* (Convolvulaceae) as well as various ornamental plants (chrysanthemums, carnations and *Pelargonium*) (Smith *et al.*, 1997; CABI, 2017).

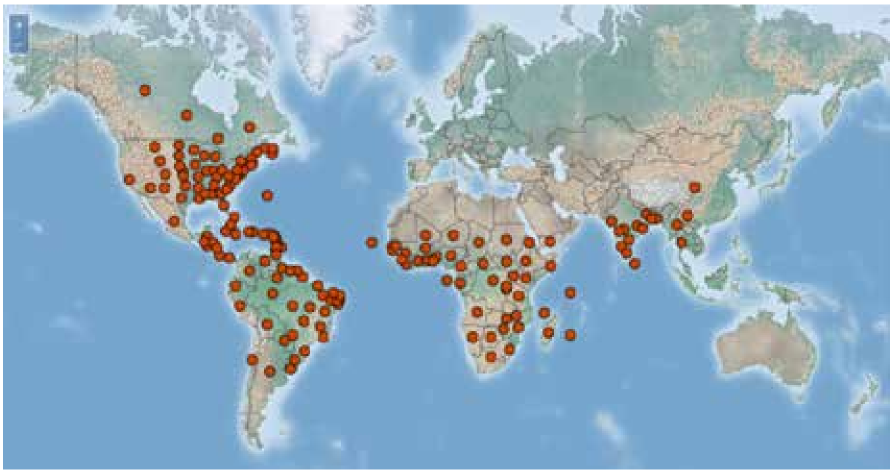

Figure 6.16.2 *Ceratitis capitata* distribution map © CABI

Figure 6.16.3 *Spodoptera frugiperda* larval damage on maize © University of Georgia, Bugwood.org

Figure 6.16.4 *Spodoptera frugiperda* egg mass © Fera

Figure 6.16.5 *Spodoptera frugiperda* larva © Fera

Figure 6.16.6 *Spodoptera frugiperda* adult at rest, lateral view © Mark Dreiling, Bugwood.org

Description

The eggs (Figure 6.16.4) are dome shaped measuring about 0.4 mm in diameter and 0.3 mm in height. The number of eggs per mass varies considerably but is often in the range of 100 to 300. The eggs are sometimes deposited in layers, but most eggs are spread over a single layer attached to foliage. The female also deposits a layer of greyish scales between the eggs and over the egg mass, imparting a furry or mouldy appearance.

Young larvae are greenish with a black head, the head turning orangish in the second instar. In the second, but particularly the third instar, the dorsal surface of the body becomes brownish, and lateral white lines begin to form. In the fourth to the sixth instars the head is reddish brown, mottled with white, and the brownish body bears white subdorsal and lateral lines (Figs 6.16.1 and 6.16.5). Elevated spots occur dorsally on the body; they are usually dark in colour, and bear spines. The face of the mature larva is also marked with a white inverted "Y" and the epidermis of the larva looks rough or granular in texture when examined closely.

The adult moths (Figs 6.16.1 and 6.16.6) have a wingspan of 32 to 40 mm. In the male moth, the forewing is generally shaded grey and brown, with triangular white spots at the tip and near the centre of the wing. The forewings of females are less distinctly marked, ranging from a uniform greyish brown to a fine mottling of grey and brown. The hind wing is iridescent silver-white with a narrow dark border in both sexes (EPPO, 2015b).

Biology

Eggs are laid at night on the leaves of the host, stuck to the under surface of the lower part of the lower leaves in tight clusters of 100-300, sometimes in two layers, and usually covered with a protective layer of abdominal bristles. Total egg production per female averages about 1500 with a maximum of over 2000. Hatching requires 2-10 days (usually three to five days; two to three days in the summer months). There are usually six larval instars. The young larvae feed deep in the whorl; the first two larval instars feed gregariously on the underside of the young leaves causing a characteristic skeletonizing or 'windowing' effect, and the growing point can be killed. Larger larvae become cannibalistic and thus one or two larvae per whorl is usual. The rate of larval development through the six instars is controlled by a combination of diet and temperature conditions, and usually takes 14-21 days; 14 days in the summer and 30 days during cool weather. Larvae tend to conceal themselves during the brightest time of the day. Larger larvae are nocturnal unless they enter the armyworm phase when they swarm and disperse, seeking other food sources. Pupation normally takes place in the soil inside a loose cocoon in an earthen cell, or rarely between leaves on the host plant, and 9-13 days are required for development. Adults emerge at night, and are most active during warm, humid evenings. After a preoviposition period of three to four days, the female normally deposits most of her eggs during the first four to five days of life, but some oviposition occurs for up to three weeks. Females typically use their natural pre-oviposition period to fly for many kilometres before they settle to oviposit, sometimes migrating for long distances. On average, adults live for 10-14 days, ranging from about seven to 21 days.

A threshold temperature of 10.9°C and 559 day-degrees C are required for development. Sandy-clay or clay-sand soils are suitable for pupation and adult emergence, and emergence in these soil types is directly proportional to temperature and inversely proportional to humidity. Above 30°C the wings of adults tend to be deformed. Pupae require a threshold temperature of 14.6°C and 138 day-degrees C to complete their development (Ramirez-Garcia *et al.*, 1987).

Spodoptera frugiperda is a tropical species adapted to the warmer parts of the New World; the optimum temperature for larval development is reported to be 28°C, but it is lower for both oviposition and pupation. In the tropics, breeding can be continuous with four to six generations per year, but in northern regions only one or two generations develop; at lower temperatures, activity and development cease, and when freezing occurs all stages are usually killed. In the USA, *S. frugiperda* usually overwinters only in southern Texas and Florida. In mild winters, pupae survive in more northerly locations.

Dispersal and Detection

Spodoptera frugiperda is a regular annual migrant in the Americas, dispersing throughout the USA and flying into southern Canada virtually every summer. It is suggested that, in this species, migration has evolved as a major component in the life history strategy. The use of the pre-oviposition (maturation) period for widespread dispersal seems to be very effective. In the USA, adult moths have been recorded using a low-level jet stream, which took them from Mississippi to Canada in 30 hours (CABI, 2017). Larvae frequently exhibit armyworm behaviour in late summer or early autumn and local dispersal is thus successfully accomplished, helping to reduce larval mortality.

In most years larvae arrive in Europe carried by air-freight on vegetables or fruit from the New World; sometimes they are also intercepted on herbaceous ornamentals (Seymour *et al.*, 1985).

Spodoptera frugiperda can be detected by searching fields for leaf feeding damage and by using pheromone traps.

Economic and other Impacts

Spodoptera frugiperda is found widely throughout the warmer parts of the New World. Damage results from leaf-eating and healthy plants usually recover quite quickly, but a large pest population can cause defoliation and resulting yield losses; the larvae then migrate to adjacent areas in true armyworm fashion. Caterpillars of *S. frugiperda* appear to be much more damaging to maize (*Z. mays*) in West and Central Africa than most other African *Spodoptera* species. The overall costs of losses for maize (*Z. mays*), sorghum (*S. bicolor*), rice (*Oryza* spp.) and sugarcane (*S. officinarum*) in Africa are estimated to be approximately US$ 13,383m (Abrahams *et al.*, 2017). This does not take into account up to 80 other crops the insect has been known to feed on, as well as subsequent seed lost for the following growing seasons.

6.17 White Cedar Thrips

Order: Thysanoptera
Family: Phlaeothripidae
Species: *Holopothrips tabebuia* Cabrera & Segarra

	Present l	Threat		
	Absent ¡	Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	l			
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.17.1 White cedar or pink trumpet tree *Tabebuia heterophylla* foliage severely deformed by galls induced by *Holopothrips tabebuia* © C. Malumphy

Background

In 2001 *Tabebuia* trees in Florida (USA) were observed with dramatically deformed galled foliage (Figs 6.17.1 and 6.17.3-6.17.5). The cause of this distorted foliage was found to be an invasive alien unnamed thrips that was subsequently described under the name *Holopothrips tabebuia* (Cabrera & Segarra, 2008). It has spread rapidly in the Dominican Republic, Puerto Rico (Jenkins, 2013) and the British Virgin Islands. It is commonly called the white cedar gall thrips, white cedar thrips and *Tabebuia* gall thrips. The pest poses a plant health risk to all the UKOTs in the Caribbean, wherever *Tabebuia* species occur. It can cause serious damage to new growth and young plants (Fig. 6.17.1) even leading to mortality.

Geographical Distribution

Holopothrips tabebuia is native to the Neotropical region but its precise geographical origin remains unclear. It has been introduced to the USA (Florida, since 2001), Puerto Rico (since 2006), Dominican Republic, Guadeloupe (since 2007), Martinique (since 2007), British Virgin Islands (Tortola, since 2009), and Saint Lucia (originally misidentified as *H. inquilinus* (Bournier)) (Cabrera & Segarra, 2008; Michel *et al*., 2008; Jn Pierre, 2008). Galls on *Tabebuia* plants suspected to be caused by *H. tabebuia* have also been observed in the Bahamas (2012), Dominica, and Saba and Sint Eustatius.

Figure 6.17.2 *Holopothrips tabebuia* adult in liquid, showing the bicoloured body and delicate wings © Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org

Figure 6.17.3 *Holopothrips tabebuia* attacks the new growth of *Tabebuia* species causing the leaf edges to become crinkled, folded and rolled, British Virgin Islands © C. Malumphy

Figure 6.17.4 *Tabebuia heterophylla* foliage galled by *Holopothrips tabebuia*; the thrips is having a social impact in the British Virgin Islands where the white cedar *Tabebuia heterophylla* is the Territorial Tree and Territorial Flower © C. Malumphy

Figure 6.17.5 Apical growth of *Tabebuia heterophylla* can be severely damaged and young plants killed by *Holopothrips tabebuia*, British Virgin Islands © C. Malumphy

Host Plants

Holopothrips tabebuia feeds on *Tabebuia* spp. (Bignoniaceae) and exhibits a preference for *T. heterophylla* (pink trumpet tree, white cedar, roble rosada, roble blanco), and to a lesser degree *T. aurea* (silver trumpet tree). The genus *Tabebuia* contains approximately 67 species native to the American Tropics that range from Mexico in the north to Argentina in the south, and throughout the Caribbean.

Small numbers of adult *H. tabebuia* have also been found on black-calabash *Amphitecna latifolia* (Bignoniaceae), calabash *Crescentia cujete* (Bignoniaceae) and umbrella plant *Schefflera actinophylla* (Araliaceae), although there is no evidence of any biological association with these plants because they were lacking galls (Cabrera & Segarra, 2008).

Description

The adult thrips are about 2.0-2.5 mm in length, have fully developed, delicate wings (Fig. 6.17.2) and distinctly bicoloured bodies (Fig. 6.17.2). The head, thorax and body are mainly yellow to brownish-yellow and the tip of the abdomen is dark brown. A detailed morphological description and illustrations of adult *H. tabebuia* are provided by Cabrera and Segarra (2008).

Holopothrips is a Neotropical genus of about 30 described species (Mound, 2007) that may be identified with the key by Mound and Marullo (1996). Using this key, *H. tabebuia* keys out closest to *H. inquilinus*, a species described from cecidomyid galls on an unspecified host on Guadeloupe (Bournier, 1993). The two species are readily distinguished morphologically using the descriptions provided by Cabrera and Segarra (2008).

Biology

Adults and larvae of *H. tabebuia* feed on the young foliage at the growing tips, inducing obvious deformations (Figs 6.17.1 and 6.17.3-5) that become more conspicuous as the infested leaves mature. The leaf edges become crinkled, folded and rolled producing a gall in which all developmental stages of the thrips coexist. The galling is usually much more pronounced on the foliage of *T. heterophylla* than on other *Tabebuia* spp.. In Puerto Rico the severity of the attack seems more prevalent in humid districts (Cabrera *et al.,* 2008). The anthocorid bug *Montandoniola moraguezi* (Hemiptera: Anthocoridae) has been observed predating on the thrips inside the galls. Mealybugs (Pseudococcidae) also occur inside the thrips galls.

Dispersal and Detection

Thrips of this species are most likely to be first detected by the presence of the conspicuous galls (Figs 6.17.1 and 6.17.3-5). There appears to be no published research on the dispersal rate of *H. tabebuia*, but the adults are winged, and it was recorded spreading rapidly in Puerto Rico wherever suitable host plants were available. It has also spread rapidly in Tortola, British Virgin Islands.

Economic and other Impacts

There do not appear to be any published reports of *H. tabebuia* having a significant economic impact, but it has killed young plants in the BVI. *Holopothrips tabebuia* is common and widespread in Puerto Rico and Tortola causing conspicuous galling to the young foliage of *T. heterophylla*, yet infested mature trees continue to flower and produce seeds. The long-term effects on the plants are unknown.

The extensive galling of new growth reduces the aesthetic appearance of the plants and therefore may lower their commercial value in nurseries. The thrips may have a more significant social impact in the BVI, where the white cedar is the Territorial Tree and Territorial Flower.

6.18 Western Flower Thrips

Order: Thysanoptera
Family: Thripidae
Species: *Frankliniella occidentalis* (Pergande)

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.18.1 Western flower thrips, *Frankliniella occidentalis* nymphs (left) and adult (right) © David Cappaert, Bugwood.org

Background

The western flower thrips, *Frankliniella occidentalis*, is an invasive species and the most economically important of the approximately 5500 described species of thrips. These thrips cause enormous global damage by feeding on greenhouse vegetable and ornamental crops and by transmitting plant-pathogenic tospoviruses. Its invasiveness is largely attributed to the international movement of plant material and insecticide resistance, both of which have combined to foster the rapid spread of the species throughout the world (Kirk & Terry, 2003). Individuals are very small and reside in concealed places on plants; they are thus easily hidden and hard to detect in transported plant material. They reproduce rapidly and are highly polyphagous, breeding on many horticultural crops that are transported around the world.

Frankliniella occidentalis is listed on the EPPO A2 pest list as a species recommended for regulation as a quarantine pest in the EPPO region (version 2005-09). It has now reached many countries, and thus poses a significant economic plant health risk to all the UKOTs.

Geographical Distribution

Frankliniella occidentalis is native and naturally abundant on many wild flowers in western North America, west of the Rocky Mountains from Mexico to Alaska, but since the 1970s has established across North America and invaded most countries in the world. It is now present on every continent but Antarctica (CABI, 2017).

Figure 6.18.2 Western flower thrips damage © David Cappaert, Bugwood.org

Figure 6.18.3 Brown, scarred, necrotic tissue on cabbage caused by the western flower thrips © Paul Bachi, University of Kentucky Research and Education Center, Bugwood.org

Figure 6.18.4 Adult western flower thrips feeding in a flower in ornamental greenhouse © David Cappaert, Bugwood.org

Figure 6.18.5 Western flower thrips adults © Mohammad Mirnezhad, Leiden University, Bugwood.org

Host Plants

The western flower thrips is a polyphagous species with at least 250 plant species from more than 65 families being listed as hosts (CABI, 2017). As a pest it is found both outdoors and in glasshouses, and it attacks flowers, fruits and leaves of a wide range of cultivated plants (Figs 6.18.2-6.18.4). Some examples of host plants are alfalfa (*Medicago sativa*), apricot (*Prunus armeniaca)*, globe artichoke (*Cynara scolymus*), *Dianthus caryophyllus*, *Chrysanthemum indicum*, maize (Zea mays), cotton (*Gossypium hirsutum*), cucumber, (*Cucumis sativus*), aubergine (*Solanum melongena*), *Gerbera* jamesonii, *Gladiolus* spp., *Citrus paradise, Vitis* spp., *Impatiens* spp., melon (Cucumis melo), peach (*Prunus persica*), peanut (*Arachis hypogaea*), pea (*Pisum sativum*), pepper (*Capsicum* spp.), plum (*Prunus domestica*), *Bidens bipinnata*, *Fragaria* spp., tomato (*Solanum lycopersicum*), and *Raphanus raphanistrum*. However, it should be noted that a species classified as a host may not be able to support reproduction of the western flower thrips (CABI, 2017).

Description

The eggs are small (550 µm x 250 µm), opaque and kidney-shaped and are inserted into any non-lignified tissue of a plant (e.g. leaves, flower structures or fruit). Larvae are small, spindle-shaped, creamy-white in colour and wingless and may be found in flowers (Fig. 6.18.1), buds, or places where leaves are touching. The prepupa is characterized by short wing buds and antennae that are not pulled back over the head. The pupae have longer wing buds, and the antennae are pulled backward over the head. These non-feeding life stages are usually found in the soil surface area, although they can occur in complex flowers like chrysanthemum. Both pupal stages are usually white to cream coloured. Adults have fully developed wings with long fringes of cilia typical of most Thysanoptera (Figs. 6.18.1 and 6.18.5). The adults of this species are slender and less than 2 mm in length. There are three colour morphs. These colour morphs are termed dark-brown, light, and intermediate (yellow with a dark longitudinal band along the dorsum of the thorax and the abdomen). Males usually make up a much smaller proportion of the population and are smaller with a narrower abdomen, and paler than females. Adults and larvae may be found in similar locations (CABI, 2017).

Biology

Western flower thrips, will reproduce continuously if environmental conditions are favourable, with up to 15 generations in a year being recorded under glass (Lublinkhof & Foster, 1977). Development and reproductive rates are temperature dependent. The total life cycle from egg to egg has been recorded as 44.1, 22.4, 18.2 and 15 days at 15, 20, 25 and 30°C, respectively.

Adult thrips will enter closed buds, where they oviposit their eggs into the soft mesophyll but they will also oviposit in similar tissues of leaves, flower parts and fruits. Each female typically lays between 20 and 40 eggs during its life (CABI, 2017). Eggs hatch in about 4 days at 27°C, but take 13 days at 15°C. There are two actively feeding, mobile, larval stages and two non-feeding pupal stages. Larvae begin feeding soon after emergence, and moult within 3 days at 27°C (7 days at 15°C). Second instar larvae are very active, often seeking concealed sites for feeding, and they develop to the prepupal stage in about 3 days at 27°C or 12 days at 15°C. When attacked by predators, larvae produce an alarm pheromone in an anal droplet, which signals conspecifics to disperse (Teerling *et al.*, 1993). At the end of the second larval stage, larvae normally drop to the ground to seek a pupation site. The pupation site varies; most commonly it is in the surface layer of dead leaves beneath a plant, rather than in the soil, or even on the plant itself. The prepupa matures rapidly (1 day at 27°C; 4 days at 15°C), but the pupal stage usually takes more than a week before the adult is ready to emerge.

Newly emerged females are relatively inactive during their first 24 hours, but soon become active, particularly at higher temperatures. Females may live for about 40 days under laboratory conditions, but they can survive as long as 90 days. Males typically live only half as long as females. Females undergo a preoviposition period, the duration of which is temperature dependent (Lublinkhof & Foster, 1977). Once oviposition begins, females will lay eggs throughout adulthood. At 27°C, females lay a mean of 0.66 to 1.63 eggs per day, but the number of eggs each female lays per day can be quite variable (Reitz, 2008). The larvae and adults feed on the contents of plant cells by using their mandibles to create a hole into which they insert their maxillae, they also ingest pollen grains and animal prey such as spider mite eggs (Cluever *et al.*, 2015).

Adult males form mating aggregations on bright, sunlit objects such as flowers. Females visit the aggregations, mate and then leave. Males are haploid, produced from unfertilized eggs, whereas females are diploid and derived from fertilized eggs. Most populations have female biased sex ratios, possibly because males have a shorter adult life, but it has yet to be determined if mated females exert control over the sex of offspring (CABI, 2017).

Dispersal and Detection

Natural dispersal of western flower thrips is likely to be limited as they are not strong fliers, but they do have the ability to fly and can easily be transported over relatively long distances by wind and human-assisted transport. Most invasions have been associated with transportation of infested plant material due to their small size and cryptic habits (Morse & Hoddle, 2006).

Detection is usually by assessing and checking for feeding damage, shaking flowers over a white tray or by the use of blue/yellow sticky traps.

Economic and other Impacts

Frankliniella occidentalis affects numerous economically important crops directly by reducing yield and market quality through feeding damage or by transmission of viral pathogens, and indirectly when the mere presence of thrips on a crop is used as a reason for denying it entry to a profitable market. It is the most serious insect pest of most glasshouse crops worldwide (Cloyd, 2009) and is also a major pest of some outdoor crops in warm climates e.g. *Phaseolus vulgaris* in Kenya (Gitonga *et al.*, 2002) and fruiting vegetables in Florida USA (Demirozer *et al.*, 2012). The effects are more serious when the thrips population carry virus. Outbreaks can cause complete crop loss.

Worldwide crop damage from tospoviruses transmitted by *F. occidentalis* has been estimated to exceed US$ 1 billion per year (Goldbach & Peters, 1994). In addition to the major economic impact this of this species, it also affects the environment. Resistance to insecticide control has quickly developed, leading to misuse and overuse of these chemicals, which in turn not only increases production costs but also reduces natural enemies and disrupts Integrated Pest Management schemes, including that for other pests.

6.19 Melon Thrips

Order: Thysanoptera
Family: Thripidae
Species: *Thrips palmi* Karny

	Present l Absent ¡	Threat Bio	Threat Hlth	Threat Econ
Ang	¡			ü
Ber	¡			ü
BVI	l			
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.19.1 Adult female melon thrips *palmi* © Crown copyright

Background

The melon thrips, *Thrips palmi*, is an invasive Asian pest of a wide range of glasshouse and field ornamental and vegetable crops, particularly plants in the families Cucurbitaceae and Solanaceae, such as cucumber (*Cucumis sativus*), aubergine (*Solanum melongena*), tomato (*Solanum lycopersicum*) and sweet pepper (*Capsicum* spp.). Their mouthparts are adapted to piercing and sucking, and adults and nymphs both feed by sucking the cell contents from leaves, flowers and fruits, thereby causing surface silvery scars, and leaf deformation or chlorosis. The thrips is widespread in the Caribbean but has not been recorded from most of the UKOTs. It is not only a primary plant pest but vectors plant pathogenic viruses and is regulated in the European Union.

Geographical Distribution

The pest appears to have originated in southern Asia and to have spread from there during the latter part of the twentieth century. It is now widespread in both Asia and the Pacific region, as well as the Caribbean. It has also been recorded locally in North, Central and South America, Africa and Australia. The species continues to expand its range, although it does appear to be restricted by certain climatic conditions (cooler temperatures and aridity). The species may well one day become pantropical.

In the Caribbean it has been recorded from Antigua and Barbuda, Bahamas, Barbados, British Virgin Islands, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago (CABI, 2017).

Figure 6.19.2 Second instar larva of *Thrips palmi* © Crown copyright

Figure 6.19.3 *Thrips palmi* feeding on the underside of a leaf © Crown copyright

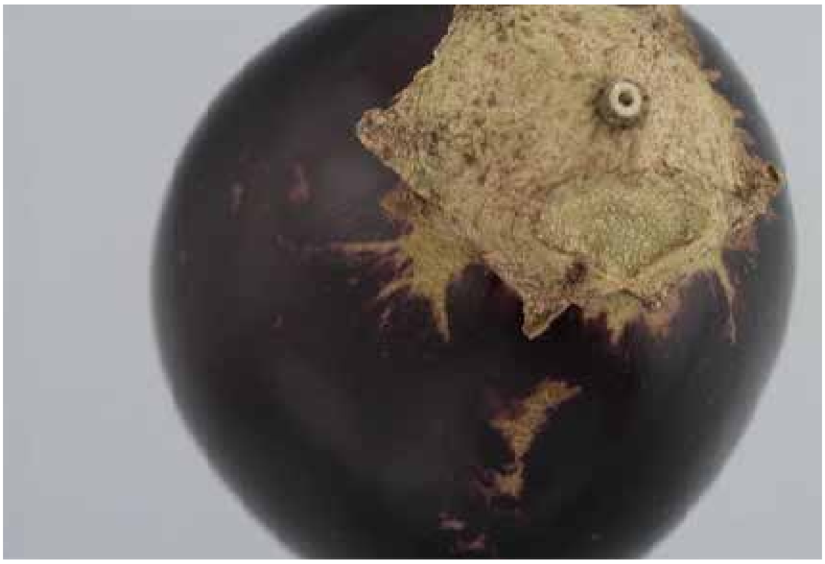

Fig. 6.19.4 Surface scarring on an aubergine caused by *Thrips palmi* feeding © Crown copyright

Host Plants

Thrips palmi is extremely polyphagous, and has been recorded on more than 200 plant species from more than 36 plant families, although it has become particularly recognised as a major pest of hosts in the Curcurbitaceae and Solanaceae (Girling, 1992; CABI, 2017). Examples of its many recorded hosts include pepper (*Capsicum annuum*), *Chrysanthemum* spp., melon (*Cucumis melo*), *Cucurbita* spp., *Cyclamen*, soybean (*Glycine max*), cotton (*Gossypium* spp.), sunflower (*Helianthus annuus*), tobacco (*Nicotiana tabacum*), Orchidaceae, *Phaseolus vulgaris*, *Sesamum indicum*, tomato (*Solanum lycopersicum*), aubergine (*Solanum melongena*), potato (*Solanum tuberosum*) and cowpea (*Vigna unguiculate*).

Description

Thrips palmi adults are almost entirely yellow in colouration, although a dark longitudinal line is formed by the joining of the wings when they are held at rest (Fig. 6.19.1). The creamy-yellow larval (immature) stages lack wings but are otherwise generally similar in appearance to the adults (Fig. 6.19.2). Identification of the thrips is hampered by both their small size (1.0-1.3 mm) and their great similarity to other yellow or predominantly yellow species of *Thrips*. Within a glasshouse context, species that might be confused with *T. palmi* include the onion thrips (*Thrips tabaci*) and western flower thrips (*Frankliniella occidentalis*). *Thrips palmi* can only be distinguished with certainty from other species of thrips by means of laboratory examination.

Biology

Eggs are laid within plant tissue (leaf, flower or fruit) and are not visible to the naked eye. There are two larval stages, which are active feeders and may potentially be found on any above-ground part of the plant, and then two pupal stages. The latter are sedentary and non-feeding, though will move if disturbed; the second-stage larva usually drops to the soil to pupate, but occasionally the pupae can be found on the aerial parts of the plant. When the adults emerge, they return above ground to feed and lay eggs. At 25°C, a single life cycle may be completed in as little as 17.5 days (EPPO, 1989).

Dispersal and Detection

On plant material, *T. palmi* may potentially be found on most above-ground parts of the plant (leaves, flowers and fruits); the parts of the plant infested can differ according to variables such as the host and the characteristics of different *T. palmi* populations. As a result, the thrips have the potential to be imported on a wide range of plants for planting, cut flowers, and fruits of host species. During visual examination of plant material, attention should be paid to silvery feeding scars on the leaf surfaces, particularly on the undersides of leaves (where the larvae are most likely to be found; Fig. 6.19.3) and especially along the midrib and the veins, as well as to flowers and fruits. Heavily infested plants are often characterised by a silvered or bronzed appearance to the leaves, stunted leaves and terminals, or scarred and deformed fruits. On fruit such as aubergine the larvae are usually hidden under the calyx, but scarring damage caused by feeding activity will often be visible beyond the cover of the calyx (Fig. 6.19.4). The potential presence of pupae in the growing medium also poses a risk and a barrier to detection.

Economic and other Impacts

Thrips palmi causes economic damage to plant crops both as a direct result of its feeding activity and from its ability to vector tospoviruses such as Groundnut bud necrosis virus, Melon yellow spot virus and Watermelon silver mottle virus. Its ability to transmit other tospoviruses such as Tomato spotted wilt virus remains unverified. Both larvae and adults feed gregariously, and under the right conditions numbers can build up rapidly leading to heavy infestations and severe damage to plants. The particularly large host range of the thrips means that it could threaten a wide range of indoor and outdoor grown crops within the UKOTs, with the potential to cause significant economic impacts. The thrips is regulated in the European Union and the presence of the thrips on vegetables grown for export to the EU could lead to their destruction.