Department
for Environment
Food & Rural Affairs

fera

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

PART 5 – INVERTEBRATES (except insects) & REFERENCES

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

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

Part 5 Invertebrates (except insects) & References

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

First Edition

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

https://fera.co.uk/

Published digitally: May 2019

© Crown copyright 2019

Suggested citation: Malumphy, C., Reid, S., Down, R., Dunn., J., Collins, D. & Matthews, J. 2019. Field Guide to Invasive Alien Invertebrate Pests in the South Atlantic UK Overseas Territories. Part 5 – Invertebrates (except insects) & References. Defra/Fera. 49 pp.

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

Contents

PART 3 – INSECTS (termites, beetles, earwigs and flies)

6.27 Potato Cyst Nematode

Order: Tylenchida
Family: Heteroderidae
Species: *Globodera rostochiensis* (Wollenweber) and *Globodera pallida* (Stone)

	Present l / Absent ¡	Threat Bio	Threat Hlth	Threat Econ
SH	¡			
Asc	¡			
Tris	¡			ü
FI	l			
SG	¡			
BAT	¡			

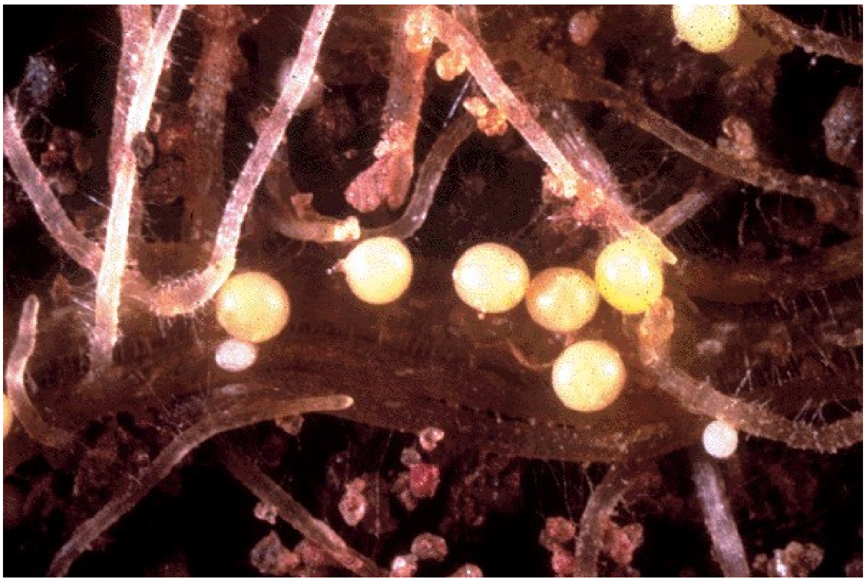

Figure 6.27.1 Females of *G. pallida*. As development proceeds, the white females die and turn into brown cysts containing eggs © Fera Science Ltd

Background

Potato cyst nematodes (PCN) comprise of two very closely related species, *Globodera rostochiensis* and *Globodera pallida*, which co-evolved with the potato in South America but have subsequently been introduced elsewhere with the production of potatoes. As such, these species are considered quarantine pests of actual or potential economic importance wherever potatoes are grown or traded throughout the world (EPPO, 2017; van Riel and Mulder, 1998). They occur in large soil masses and also adhere to potato tubers as microscopic cysts, which represent a complex of morphologically identical, but behaviourally different virulence groups or pathotypes. This presents major problems for their detection, identification and management (EPPO, 2017; van Riel and Mulder, 1998).

Geographical Distribution

PCN originated in the Andes Mountains in South America, from where it has spread with the introduction of potatoes to other regions. The present distribution covers temperate zones down to sea level and in the tropics at higher altitudes. In these areas, distribution is linked with that of the potato crop (Sullivan et al., 2007; van Riel and Mulder, 1998). *G. pallida* has been recorded as present in the Falkland Islands since 1992 (CABI, 2018; Zaheer et al., 1992).

Figure 6.27.2 Yellow potato cyst nematode *Globodera rostochiensis* females on potato roots © Bonsak Hammeraas, NIBIO - The Norwegian Institute of Bioeconomy Research, Bugwood.org

Figure 6.27.3 White potato cyst nematode *Globodera pallida* females on potato roots © Bonsak Hammeraas, NIBIO - The Norwegian Institute of Bioeconomy Research, Bugwood.org

Figure 6.27.4 Brown cysts containing eggs © Janet A. Rowe

Figure 6.27.5 Field symptoms of PCN infestation on potatoes. Note yellowed and stunted plants © Florida Division of Plant Industry Archive/Florida Dept. of Agriculture & Consumerservices/ Bugwood.org - CC BY 3.0 US

Hosts

The major hosts of *G. pallida* and *G. rostochiensis* are restricted to the Solanaceae, in particular potato (*Solanum tuberosum*), tomato (*S. lycopersicum*) and aubergine (*S. melongena*) (Roberts and Stone, 1981; Sullivan et al., 2007).

Description

The female colour at the appropriate stage of development can be used as an indication of species: a female which changes during maturation from white to yellow, then into a brown cyst, is likely to be *G. rostochiensis* (Fig. 5.32.2), while one which changes from white directly to brown is likely to be *G. pallida* (Fig. 5.32.3) (Stone, 1973a and Stone 1973b).

In general, *Globodera* cysts are rounded with a small projecting neck, no terminal cone is present, diameter ± 450 µm, and they have a tanned brown skin (Fig 5.32.4). The cuticle surface has a zigzag pattern of ridges and a distinct D-layer is present. The eggs are retained within the cyst, no egg-mass is present (Stone 1973a; Stone 1973b; EPPO 2017).

The second-stage juvenile, the infective stage in the life cycle, hatches directly from the egg where it has already undergone a moult. They are mobile, vermiform in shape, annulated and taper at head and tail regions. The juveniles of *G. pallida* and *G. rostochiensis* are very alike, but *G. pallida* juveniles are generally longer as are their stylets (approximately length of juveniles: 445-510 µm long) (Stone 1973a; Stone 1973b; EPPO 2017).

Males are vermiform and relatively more abundant when environmental conditions are poor as they require less food than females and do not feed during the free-living stage (Evans, 1970). The vermiform males have a short life span of ten days or so and, during this time, will mate with as many available females as possible which secrete a pheromone to attract them (Evans, 1970; Green and Miller, 1969).

Biology

PCN cysts can contain as many as 500 eggs and can remain viable for many years before gradually deteriorating. Egg hatch is dependent on soil moisture, temperature, chemical exudates from potato roots, and day length. *G. pallida* eggs are adapted to hatch and develop at cool temperatures (10-18°C) whereas *G. rostochiensis* eggs are adapted to a higher temperature range of 15-25°C (Franco, 1979; Hominick, 1986).

The juvenile nematodes move between soil particles and locate and invade potato roots. Once inside the root, the nematode punctures the plant cells and feeds with its needle-like stylet. Feeding induces changes in the plant root cells which become abnormally large. Female nematodes which establish feeding sites on the roots become sedentary and progressively enlarge, rupturing the outer root tissue. Slender, male nematodes leave the roots and mate with females which now only have their heads embedded in the root and the posterior parts of their bodies exposed. Once fertilised, eggs develop inside the females which die about the same time as the potato crop flowers, becoming the brown cysts on the outside of the roots. When potato plants are lifted, the mature cysts drop off and remain dormant in the soil until further crops of potatoes are grown. In general, only one life cycle occurs on each growing crop and takes from 38-48 days to complete (CABI, 2018).

Dispersal and Detection

Natural dispersal is limited as the infective second stage juveniles only move at a maximum of about 1 m in the soil. However, cysts can be transported by wind and flood water. Most movement to new localities is by passive transport. The main routes of spread are infested seed potatoes and movement of soil (e.g. on farm machinery, boots, bins and plants) from infested land to other areas. Infestation occurs when the second-stage juvenile hatches from the egg and enters the root near the growing tip by puncturing the epidermal cell walls, and then internal cell walls, with its stylet. Eventually it begins feeding on cells in the pericycle, cortex or endodermis (EPP0, 2013).

Detection based on host plant symptoms are not specific. General symptoms include patches of poor growth in the crop, with plants sometimes showing yellowing, wilting or death of foliage; tuber size is reduced as a result, sometimes even when only minor symptoms are visible. However, many other causes can lead to these symptoms. Plants should therefore be lifted for a visual check on the presence of cysts and young females on the roots, or a soil sample should be taken for testing. Young females and cysts are just visible to the naked eye as tiny white, yellow or brown globes on the root surface. Detection by lifting plants is only possible during a very narrow time lapse and is time-consuming. Soil testing is therefore the best way of determining the presence of potato cyst nematodes. Statutory sampling procedures and details of sampling and extraction methods can be found in EPPO Standard PM 3/30 (OEPP/ EPPO, 1991). Detection based on host plant symptoms and identification by morphological and molecular methods is detailed in EPPO, 2017.

Economic and other Impacts

Potatoes are one of the top five important food and cash crops. PCN cause extensive damage, particularly in temperate areas and particularly when virulent PCN populations occur and any resistance has failed. The situation is worse with *G. pallida*, where commercial cultivars with good resistance are still limited and those that do, have undesirable characteristics. Economic loss due to PCN is estimated at around £50 million per annum and for Europe several times this amount (CABI 2018). PCN damage is related to the number of viable eggs per unit of soil and is reflected in the weight of tubers produced (Been et al., 1995; Elston et al., 1991; Philips et al., 1991).

6.28 Brown centipede

Order: Lithobiomorpha
Family: Lithobiidae
Species: *Lithobius forficatus* (Linnaeus)

	Present l / Absent ¡	Threat Bio	Threat Hlth	Threat Econ
SH	l			
Asc	¡	ü		
Tris	¡	ü		
FI	¡	ü		
SG	¡	ü		
BAT	¡			

Figure 6.28.1 *Lithobius forficatus* adult found alive under plywood in the Falkland Islands © Fera

Background

Lithobius forficatus, most commonly known as the brown centipede or stone centipede, is a common European centipede of the family Lithobiidae. It has been spread around the world by human activity as it commonly occurs in urban areas, in buildings and in waste and storage areas. Being a predatory organism that feeds on a variety of invertebrate taxa, it may have an ecological effect on the abundance of native soil-dwelling invertebrates in areas it invades.

Lithobius forficatus is morphologically highly variable, it has been hypothesized that *L. forficatus* is actually a complex of cryptic species, this has been supported by molecular research (Spelda *et al*.,2011; Giska & Babik, 2016). Eason (1969) discussed characters used to separate "subspecies".

Geographical Distribution

Lithobius forficatus is native to the Holarctic region and is present throughout Europe and parts of North Africa. It was introduced to North America where it is widespread. It spread south to the South American Andean region where it has been recorded from Argentina, Chile, Colombia, Ecuador, Peru and Uruguay (Prado et al., 2018). It has also spread to Australia, New Zealand and South Africa. Of the UKOTs, it has been reported from Bermuda and Saint Helena (since 1865) (Varnham, 2006). Widespread in the higher parts of the island, it is one of three non-native Lithobiomorphs to have invaded Saint Helena (Gray, 2018). Varnham (2006) notes an unconfirmed report of it on Ascension but lists it as doubtful. There was a find of a single female *L. forficatus* in an industrial area of Stanley, Falkland Islands (F.I.) in 2013. Discovered underneath plywood, it was to send to Fera Science for identification. Initially it was thought to be another European species, *L. melanops*, which established on the F.I (Barber, 2011; Fera unpublished records) and Tristan da Cunha (Lawrence, 1956). It is undetermined whether *L. forficatus* is established in the F.I. The "native" *Anopsobius macfaydeni* is much smaller, up to 9.2mm, yellow to pale brown and known from both West & East Falkland (Barber, pers. comm)

Hosts

Centipedes are nocturnal, opportunistic carnivorous predators, feeding on a range of small ground-dwelling invertebrates, including earthworms, small millipedes, enchytraeids, collembola, insect larvae and spiders. They are known to ingest some leaf litter on occasion (Coleman *et al*., 2004), Lewis (1965) notes that *L. forficatus* takes litter throughout the year.

Description

Centipedes are distinguished from superficially similar organisms by the presence of forcipules, the modified legs of the first trunk segment upon which the head rests. This segment bears the pincerlike fangs (poison claws) which have venom ducts opening at their tips (Coleman et al, 2004).

The following description is taken from Barber (2009). *Lithobius forficatus* adults range from 18mm-30 mm long and are chestnut brown in colour (freshly moulted specimens are pale blue). They have 15 pairs of legs as adults, but hatch from the egg with a reduced number of pairs (7 plus a pair of limb-buds) and go through a series of larval stages during which further legs are added at each moult. During these stages and the succeeding post-larval ones, the number of ocelli, teeth on the forcipular coxosternite, coxal pores etc. tend to show an increase in number until they reach adulthood.

Their head is slightly broader than long, the antennae have 35-43 articles and make up approximately a third of the body length. They have 20-30 ocelli on each side of the head arranged in 5 or 6 irregular rows. The forcipular coxosternite has 5 + 5 to 6 + 7 teeth. The 9th, 11th and 13th tergites have prominent projections at their posterior angles. The female genitalia have two conical spurs, occasionally a third on one side only. The claw of the gonopod has distinct dorsal and lateral denticles.

Lithobius forficatus can be separated from *L. melanops,* another stone millipede that has invaded the Atlantic UKOTS (namely Falkland Islands, Saint Helena and Tristan da Cunha) by its size and colour. *Lithobius forficatus* is the larger species and is more or less uniform chestnut brown, reaching 30mm at maturity whereas *L. melanops* is quite light but with a broad, dark longitudinal stripe and only reaches a maximum of 17mm in length (Barber, pers. comm). Other confirmatory characters include the presence of 5-7 teeth on each side of the forcipular coxosternite for *L. forficatus*, whereas *L. melanops* usually has 2, occasionally 3 and double claws on the 15th legs (they are single in *L.forficatus*).

There are other large brown *Lithobius* species, two of which (*L.pilicornis* and the vagrant *L.peregrinus* – see Barber, 2009) have been recorded in Britain where they are generally synanthropic and might possibly reach the South Atlantic UKOTs from there or by other routes (Barber, pers comm). South Atlantic climatic conditions are probably less favourable to them though, *L. pilicornis* is limited to the South West in Britain, and *L.peregrinus* has only been recorded on development sites, in port towns in southern England and on plant imports (Fera unpublished records). There are other lithobiids around the world with various degrees of similarity to *L.forficatus* (Barber, pers comm).

Biology

Lithobiomorpha generally inhabit leaf litter, moss, bark and under fallen tree trunks and stones in a variety of environments. Like other centipedes, they favour moist environments, as they lack a waxy coating on their exoskeleton that helps to prevent water loss. In its native or invasive distribution, *Lithobius forficatus* is often very common, especially in human influenced habitats and is sometimes found inside houses, other buildings and inside glasshouses (Barber, 2008; Barber, pers. comm.).

Lithiobiomorph eggs are laid singly, and are carried at first in the genital claspers. *Lithobius forficatus* appears to lay eggs for a considerable part of the year, though there appears to be only a short period of sperm transfer in spring (Lewis, 1965). Lithobiomorphs go through a series of developmental instars and characters of the adult form with each moult (ecdysis). The earliest larval stages have fewer leg pairs (seven in *L. forficatus* hatchlings). The second developmental phase, the epimorphic phase, consists of 4 immature stages, in all of which there are fifteen pairs of legs and the sexually mature adult appears at the last one. (Cloudsley-Thompson, 1945). Development from egg to mature centipede takes roughly three years and *L. forficatus* have been known to live five to six years (references in Cloudsley-Thompson, 1945).

Small centipedes' poison fangs are usually too weak to penetrate human skin (except perhaps where it is relatively soft e.g. between the bases of the fingers) (Barber, pers.comm), and their bite typically yields only minor discomfort, no worse than that caused by a bee sting. Centipede poison, used in the capture of prey, is a cocktail of several substances, including histamine, serotonin, cardiotoxin, and a quinoline alkaloid (Coleman *et al*. , 2004).

Dispersal and Detection

Lithobius forficatus are not likely to disperse over long distances naturally, although they can move quickly when disturbed.

Accidental introduction within building material, bulk goods, plants, vegetables and hitchhiking on vehicles etc. is the most likely means of dispersal. Centipedes are nocturnal and tend to hide in small crevices and so transport via ship, trucks, containers can easily facilitate their spread. Barber (2011) noted that *L. melanops* has dispersed around the world by a result of human activity and that it most likely arrived in the Falkland Islands in material transported from the UK.

Detection during daylight hours is best done by visual inspection of suitable habitats, dark moist places such as under loose bark, stones, pots, logs etc. However, detection within shipments is more difficult due to their cryptic nature.

Economic and other Impacts

Lithobius forficatus is unlikely to have any major social or economic impacts should it invade a new geographical region such as one of the Atlantic UKOTs it has not already colonised, although centipedes can and do enter houses sometimes to the consternation of residents (Barber, pers. comm.) However, being a predatory organism that feeds on a variety of invertebrate taxa, it may have an ecological effect on the abundance of native soil-dwelling invertebrates. A major challenge in biodiversity studies is that in most cases, less than 20% of soil fauna taxa are described taxonomically (Coleman, et al. 2004), and for the microarthropods, such as the springtails, only about 10% of populations have been explored, and perhaps only 10% of species described (André *et al*., 2002).

The soil fauna consumes a wide range of organic material and are arranged in complex food webs. Macrofauna, such as insects are "bioturbators," literally movers of soil. Earthworms are even more influential, and considered primary "ecosystem engineers," moving plant and microbial residues and creating biopores in soil. A decrease in abundance of these important soil invertebrates could in turn may affect nutrient cycling and peat formation.

In the eastern USA Hickerson *et al*. (2005) studied the competitive relationships of the native centipede *Scolopocryptops sexspinosus*, and the invasive *L. forficatus*. They found that both species consumed similar prey, but the native species was competitively superior as it predated on *L. forficatus. Scolopocryptops sexspinosus* is a significantly larger species therefore this is unsurprising. Anecdotal evidence from Britain suggests that, in the locations where it occurs, the larger *L.pilicornis* may possibly out-compete *L.forficatus* (Barber, pers. comm).

6.29 Antarctic Soil Mite

Order: Sarcoptiformes
Family: Nanorchestidae
Species: *Nanorchestes antarcticus* (Strandtmann)

	Present l Absent i	Threat Bio	 Hlth	 Econ
SH	i			
Asc	i			
Tris	i			
FI	i			
SG	i	ü		
BAT	l	ü		

Figure 6.29.1 Adult Antarctic soil mite *Nanorchestes antarcticus* © BugGuide 2018 Sym P. le

Background

Nanorchestes antarcticus is a minute Antarctic mite that lives in the soil near the surface or underneath rocks where they graze on algae (Block, 1980). The mite was selected to represent all soil-living mites which pose a threat to the pristine environment of the British Antarctic Territory and South Georgia. While this datasheet was being written, published records were found that indicate *N. antarcticus* already occurs to a limited extent in BAT and South Sandwich Islands (Pugh & Convey, 2000). This datasheet is therefore intended to highlight the risks of non-native soil mites in general.

Geographical Distribution

Nanorchestes antarcticus is the southernmost occurring arthropod in the world (Block, 1980; Fitzsimmons, 1971a). It is the most widely distributed Antarctic arthropod and is found over much of the Antarctic and sub-Antarctic regions (Block, 1980; Pugh & Convey, 2000).

Host Plants

Nanorchestes antarcticus are phytophagous, feeding predominantly on gelatinous red snow algae (*Ochromonas* sp.) but the algal diet is largely determined by abundance and availability rather than by preferential selection (Block, 1980; Fitzsimons, 1971b).

Description

Nanorchestes antarcticus is a small, soft bodied, prostigmatid mite (Fig. 6.29.1). The adults have a bluish body content against a red body colouring and have legs adapted for jumping. Their cuticle is flexible with regular folding over the entire body surface (Lindsay, 1972, Rounsevell & Greenslade, 1988). Females are approximately 269µm in length. During development the mite passes through four active immature instars: larva, protonymph, deutonymph and tritonymph which resembles the adult. The eggs are approximately 105.2µm in length and are red in colour (Lindsay, 1972).

Biology

Nanorchestes antarcticus are ovoviviparous, that is the eggs develop and hatch within the body of the female. The female can incubate several eggs simultaneously which may partly account for the success of this species in its Antarctic environment. When the larvae are born, they are enveloped in two coverings – the cuticle of the pre-larva and the egg shell. The larvae have only six legs. All nymphal and adult stages have eight legs. The protonymphs are approximately 172µm long, the deutonymphs approximately 191.8µm long, and the tritonymphs 222.1µm long. As the nymphs develop certain leg setae branch and one solenidion (a chemosensory sensilla which can be used for taxonomic identification) is added (Lindsay, 1972).

The habitat of *N. antarcticus* provides a highly predictable seasonal water supply and with few interacting micro-arthropods this species is an extreme A-strategist, i.e. it is long lived with low fecundity and with very limited powers of dispersal (Rounsevell, 1977). It can tolerate a wide range of environmental temperatures (-23°C to +31°C) (Block, 1980; Fitzsimons, 1971a) but are mostly active in the Antarctic summer, from October to March, when temperatures exceed 0°C diurnally (Rounsevell, 1977). During the Antarctic winter the mites are dormant in cold, dry soil just above the permafrost to a depth of 5cm (Rounsevell, 1981).

Dispersal and Detection

Dispersal of Antarctic arthropods is mediated by mechanisms beyond the control of individuals. The main natural dispersive agents are wind, water and birds. However, wind mediated transport is not likely for these mites as they live protected under stones and amongst vegetation and would not survive the extreme low temperatures and pressures associated with high speed/high altitude winds responsible for transoceanic dispersal (Marshall & Pugh, 1996; Pugh & Convey, 2000). Nevertheless, they may be dispersed locally by passive fallout of ice and snow in the Antarctic areas (Block, 1980). Ocean currents, or hydrochory, may be the most probable means of dispersal of these mites as they do inhabit coastal regions and can tolerate seawater. There are no reports of direct bird-mediated transportation although mites are highly likely to occur in bird colonies due to their organic enrichment of the habitat. There are no reports of human mediated dispersal to date, but with the increased diversity and intensity of human activities within this region it is only a matter of time before human mediated dispersal occurs.

Due to their small size, detection is by filtering ice/surface substrate and analysing these for presence of mites by use of a microscope.

Economic and other Impacts

Nanorchestes antarcticus does not directly impose any serious economic or other impact. However, global warming could cause ice to break and ocean currents to change, and with the ability of this species to withstand a broad temperature range, and to successfully colonise new areas, it may be able to invade other regions in the Antarctic and sub-Antarctic including other UKOT territories. In pristine environments such as BAT with low natural biodiversity it is important to prevent the introduction of any alien species of soil mite.

6.30 Sheep Tick

Order: Ixodida
Family: Ixodidae
Species: *Ixodes ricinus* (Linnaeus)

	Present l Absent i	Threat Bio	 Hlth	 Econ
SH	i			
Asc	i			
Tris	i			
FI	i		ü	ü
SG	i			
BAT	i			

Figure 6.30.1 *Ixodes ricinus* adult female © Fera

Background

The sheep tick *Ixodes Ricinus*, also commonly known as the castor bean or deer tick, is a small hard-bodied tick that infests livestock, deer, dogs and a wide variety of other species including humans. This tick acts as both a vector and reservoir for a series of wildlife zoonotic pathogens, especially the agents of Lyme disease, tick borne encephalitis and human granulocytic ehrlichiosis (Rizzoli *et al.*, 2004). Each active life stage (larva, nymph and adult) attaches to a single host and feeds on blood for a period of days, before detaching and then moulting or producing eggs. Whilst attached and feeding on their host they can be dispersed over large distances. All life stages will then 'quest' for a new host using an ambush technique whereby they climb up vegetation and wait for a host to brush past. However, during 'questing' the tick loses moisture, so they descend into the vegetation to rehydrate. The ticks require a relative humidity of at least 80% to survive this off-host period and are therefore restricted to areas with moderate to high rainfall (Medlock *et al.*, 2013).

Adult *I. ricinus* climb higher in the vegetation and usually only attack large animals from the size of a hare upwards. All three stages are known to bite humans. This rather indiscriminate feeding behaviour is responsible for the broad range of pathogens that this tick can transmit (CABI, 2019).

Geographical Distribution

Ixodes ricinus occurs in cool, relatively humid, shrubby or wooded areas. In addition to deciduous and mixed forests, it can be found in more open areas when the vegetation is dense, and rainfall is abundant. This tick is endemic in most of Europe (except for the Mediterranean region, which has a warm, dry climate). It also occurs as far south as the Caspian Sea and northern Iran, as well as in forested areas of northern Africa (Sonenshine, 1991).

There are approximately 889 species of ticks worldwide. Of these, approximately 702 are classified in the family Ixodidae ('hard-ticks'). Within this family, the genus *Ixodes* includes approximately 245 species. Of these, 14 belong to the '*ricinus*' complex which includes four species (*I. scapularis*, *I. pacificus*, *I. ricinus* and *I. persulcatus*) that are considered responsible for the transmission of most pathogens of tick-borne diseases of animal and public health importance. These four species are widely distributed throughout the world (Swanson *et al.*, 2006). In addition, another species, *Ixodes urinae*, is found in both hemispheres and in Antarctica.

Ixodes ricinus distribution map © CABI

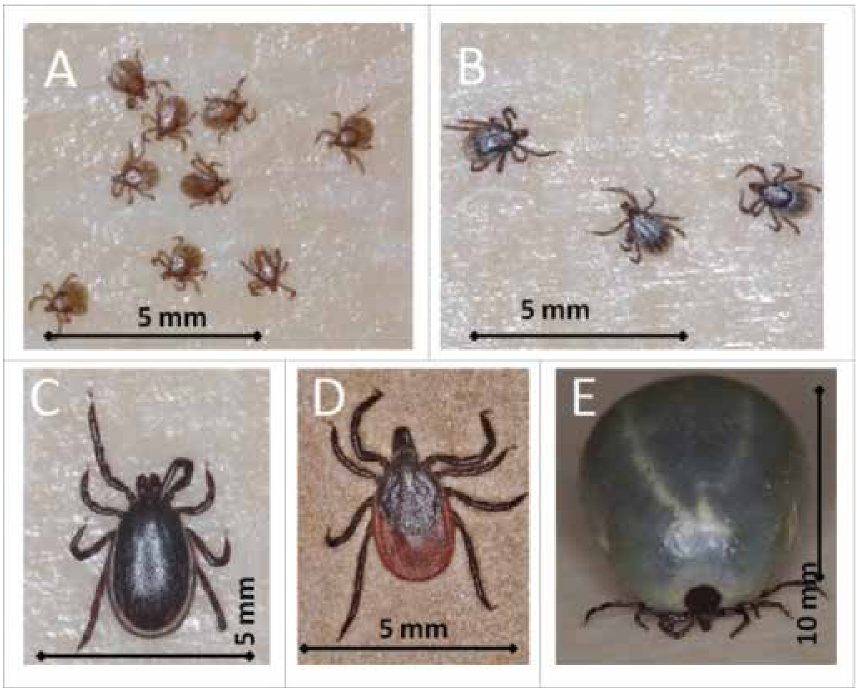

Figure 6.30.2 Life stages of *Ixodes ricinus* ticks: larvae (A), nymphs (B), adult male (C), unfed female (D), and fully engorged female (E) © Jan Erhart

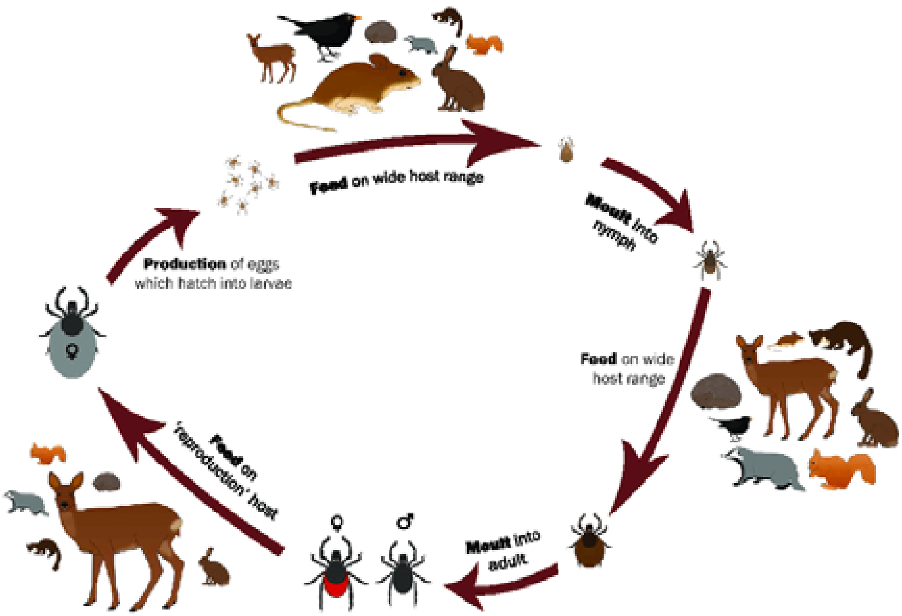

Figure 6.30.3 Schematic representation of the life cycle of *Ixodes ricinus*. Immature stages feed on a large range of host species, including shrews, voles, mice, squirrels, hedgehogs, lagomorphs, mustelids and ungulates, while adult female *I. ricinus* feed on a smaller range of hosts, including hedgehogs, hares, and ungulates. Pictures of single species represent groups of taxonomically related species. The size of the host picture represents the theorized importance of the host taxon for that life stage of *I. ricinus* © Tim R. Hofmeester

Host

Ixodes ricinus feed on a wide range of hosts including small rodents, passerines, and larger mammals like hedgehogs, hares, squirrels, wild boar and deer etc. The juvenile stages feed on the smaller hosts such as wood mice, whereas the adult stages feed on larger hosts like cattle and deer. Larger hosts are important in maintaining tick populations, with populations tending to be lower in the absence of larger hosts. Movement of hosts can also affect population numbers or result in the establishment of foci in new areas. *Ixodes ricinus* also has a high affinity for humans (Foldvari, 2016; CABI, 2019).

Description

Ixodes ricinus are hard ticks (Fig. 6.30.1) They have a dorsal shield and mouthparts that protrude forward when seen from above, they have no eyes, and the palpi are longer than they are wide. They are sexually dimorphic: the stigmatic plates are oval in males but circular in females. The ventral surface of the male has seven non-projecting, armour-like plates. The adults are red-brown in colour, but the female ticks are light grey when engorged (Fig. 6.30.2). Before feeding the males are approximately 2.5 - 3 mm long and the females 3 – 4 mm long. When they are engorged the females can be up to 10 mm in length (Kettle, 1990).

The eggs are laid in single large batches and are brown, globular, and possess a waterproofing waxy covering. The larvae are also brown, have six legs and are approximately 0.8mm in size (Fig. 6.30.2). They breathe through their skin and so water loss is exclusively through their cuticle. Once they have digested their blood meal, they moult into an octopod nymph (1.2 - 1.5mm; Fig. 6.30.2) (Kettle, 1990; Bates, 2012).

Ixodes ricinus are sometimes called castor bean ticks because the blood-gorged female resembles the mottled seeds of this plant.

Biology

Ixodes ricinus have four life stages: egg, larva, nymph and adult and a three-host life cycle (Fig. 6.30.3). Ticks must take a blood meal in order to moult to the next life stage and to produce eggs. The lifecycle is typically completed within three years but can be shorter or longer depending on climatic conditions and abundance of suitable hosts (Foldvari, 2016).

Mating usually occurs on the host and pheromones play an important role in finding a mate. Mating can last up to one week and once mated and fully engorged, an adult female will drop off a host onto the ground where she will seek conditions favourable for egg production. An engorged female will remain in this environment for four to eight weeks before eggs are produced. Up to 2000 eggs can be produced, after which the female dies and larvae hatch around eight weeks later (Foldvari, 2016).

Hungry ticks accumulate near the tips of grasses and other plants. When a host approaches, they seek to attach themselves by waving (questing) their first pair of legs. Adults seek hosts higher up the vegetation than nymphs, and nymphs higher than larvae. This is at least one of the explanations as to why adults are usually not found on rodents or lizards. The ticks remain on the host for several days (larvae 2 - 5 days; nymphs 2 - 7 days; females 6 - 11 days; and males weeks or even months). As with most members of the Ixodidae, *I. ricinus* spends 90-99% of its life off the host and has adaptive traits to withstand this, however, it cannot withstand long periods below 80% relative humidity (Jongejan & Uilenberg, 1994; Foldvari, 2016).

Dispersal and Detection

Ixodes ricinus larvae do not move horizontally over large distances so often remain aggregated within their environment whilst waiting for a host. Once on a host they may be dispersed by host movement while they feed, develop and moult to the nymphal stage. This is repeated at the nymphal and adult stage. The carriage of feeding ticks particularly by birds and large mammals is therefore crucial for their short and long-range dispersal. In addition, movement of infested livestock can increase their chances of long-range dispersal. However, *I. ricinus* is sensitive to climatic conditions and does require an animal host for all active stages for the completion of their life cycle.

Economic and other Impacts

There has been a notable increase in the prevalence of many tick-borne diseases (Parola & Didier, 2001; Randolph, 2001; Greenfield, 2011); as a result, ticks are of paramount importance globally, due to the implications on both human and livestock health.

Their ability to survive in such a diversity of habitat types and parasitize a multitude of hosts have made ticks a vector of interest over recent years. They are highly problematic in the sheep-farming and grouse-shooting industries (Davies, 2005), causing huge economic losses of several billion dollars per year, globally (Greenfield, 2011) with the deterioration of host health, including weight loss and breeding success (Balashov, 2007).

6.31 Springtail

Order: Poduromorpha
Family: Hypogastruridae
Species: *Hypogastrura manubrialis* (Tullberg)

	Present l	Threat		
	Absent ¡	Bio	Hlth	Econ
SH	¡			
Asc	¡			
Tris	¡			
FI	¡			
SG	¡	ü		
BAT	¡			

Figure 6.31.1 Dorsal view of *Hypogastrura manubrialis* found infesting mushrooms © 2016 Don Loarie, BugGuide

Background

Springtails are "decomposers" that thrive mostly on decaying organic matter, especially vegetable matter. They are an important component of the soil fauna biodiversity where they play a significant role in the nutrient cycle (Cassagne et al., 2003). They are good biodiversity indicators and can be used to record environmental impacts due to human activities (Fiera, 2009). Their name refers to the forked appendage on the underside of the abdomen that can be flicked backwards to fling the springtail into the air (Fig 6.31.2). Despite their abundance and significance, the collembolan fauna from many parts of the world are a relatively poorly studied, therefore a detailed account of the biology and distribution of *H. manubrialis* is not provided here. *Hypogastrura manubrialis* is a species within the large *H. manubrialis* 'group'.

Geographical Distribution

Hypogastrura manubrialis is distributed worldwide although it is considered introduced in the Southern Hemisphere (Pacit, 1967), where it is known from Australia, Antarctic and Sub-antarctic, South Amreica, South Africa and New Zealand (Bellinger, *et. al*., 2019). Greeslade & Convey (2012) list *H. cf. manubrialis* on Crozet Island (sub-Antarctic). There are over 7000 described spp. of springtail worldwide (Deharveng, 2004). The variety of collembolan species in an area is influenced by the soil composition such as pH, aeration, organic matter combination, nutrient, humus type, vegetation covering and the physical characteristics of the soil etc. (Qazi and Shayanmehr, 2014).

Figure 6.31.2 Ventral view of *Hypogastrura manubrialis* showing forked appendage © 2016 Don Loarie, BugGuide

Figure 6.31.3 *Hypogastrura manubrialis* head with roundish mouthcone © 2016 Don Loarie, BugGuide

Hosts

Most records of *H. manubrialis* are from compost and rich organic matter but they can also be found on the surface of puddles and water filled ditches (Hopkin, 2007). In South Africa *H. manubrialis* is typically associated with very nutrient-rich organic soils (Leinaas *et al*., 2015).

Description

Hypogastrura manubrialis is a hexapod with a body length of about 1.5mm and are greyish or reddish blue in colour (Hopkin, 2007; Qazi and Shayanmehr, 2014). There are no larval or pupal stages; the newly hatched springtails resemble the adults and reach sexual maturity before they reach maximum size. They moult several times during their life cycle, and all stages require high humidity to survive (Qazi and Shayanmehr, 2014). Under normal conditions there are probably several generations per year (Chinery 1973).

Biology

Springtails need conditions of high humidity to thrive and this is reflected in their choice of habitat such as soil, leaf litter etc. Despite their small size they may occur in huge populations and can be a significant component of the soil fauna (Barnard, 2011).

Their life cycle typically involves fertilisation of the female via a spermatophore delivered by the male. Mating behaviour can be simple or non-existent where the male simply deposits his spermatophore on the substratum at random leaving it to be discovered by the female (Hopkin, 2007). The eggs are deposited in clutches and take a few days or weeks to develop (Hopkin, 2007). After hatching they go through a series of instars, normally five, moulting every few days until they reach adulthood. They may continue to moult throughout their adult lives and can survive for more than 6 months (Hopkin, 2007).

Dispersal and Detection

Despite having no wings, springtails have considerable powers of dispersal (Hopkin, 2007). Due to their small size they are easily carried into the atmosphere by the wind and have been trapped in nets trailed by aeroplanes at heights more than 3000 metres (Hopkin, 2007). In addition, they have been known to colonise remote islands by individuals clinging to driftwood and are easily transported globally by human activities (Hopkin, 2007).

Springtails are most obvious when they ‘swarm’. Swarms occur following synchronized reproductions in conditions of ideal temperature and abundant food supply (Barnard, 2011; Hopkin, 2007).

Greenslade (2007) provides a comprehensive protocol for surveying collembola, including different collecting methods.

Economic and other Impacts

The invasion and establishment of an exotic species into an ecosystem has the potential to modify interactions between species at all trophic levels. This phenomenon is described as a trophic cascade (references in Greenslade, 2018).

Leinaas *et al*. (2015) observed high densities of *H. manubrialis* in heavily grazed vegetation in the Western Cape, South Africa, and briefly discussed the negative effect of this species on native springtail species.

Exotic invertebrates such as Collembola are a particular threat in the South Atlantic UK Overseas Territories because of the high endemism of the native fauna, in particular, to short-range endemic species by outcompeting them. Another collembolan, *H. purpurescens* is described as "highly invasive" and is thought to have displaced resident species from some habitats on the island of South Georgia (Convey *et al*., 1998.). *Hypogastura viatica* has been introduced to the Antarctic Peninsula and to a number of other sub-Antarctic Islands where it often dominates upper marine littoral habitats.

6.32 Springtail

Order: Poduromorpha
Family: Onychiuridae
Species: *Protaphorura fimata* (Gisin)

	Present l Absent i	Threat Bio	Threat Hlth	Threat Econ
SH	i			
Asc	i			
Tris	i			
FI	i			
SG	i			
BAT	l	ü		

Figure 6.32.1 *Protaphorura armata* © Creative Commons, U. Burkhardt, 2005

Background

Protaphorura fimata is a species of springtail of European origin, and like most other collembola is an important component of the soil fauna biodiversity and are useful as bio-indicators of soil quality and can be used to record environmental impacts due to human activities such as soil pollution. Hey However *Protaphorura fimata* also behaves as a plant pest, as it feeds on the germinating seeds of lettuce (*Lactuca sativa*), causing severe stand losses in parts of the USA (Joseph & Bettiga, 2016).

Despite their abundance and significance, the collembolan fauna from many parts of the world are a relatively poorly studied, therefore a detailed account of the biology and distribution of *P. fimata* is not provided here. *Protaphorura fimata* is a species within the *P. armata* 'group' (Fig. 6.32.1), and morphological characters to separate species within the group are not reliable (Hopkin, 2007).

Geographical Distribution

Protaphorura fimata was originally described from Switzerland and seems to be widely distributed in Europe (de Jong *et.al.*, 2014). It was first reported from the USA under the name *P. fimata* in 2015 from a population in California, however most US records of *P. armata* appear to refer to *P. fimata*, suggesting that the species is widespread throughout the country (Joseph *et al*. 2015). It has invaded Australia (Greenslade, 2018) where it is recorded from agricultural land. In the Antarctic *Protaphorura fimata* has been recorded on the Macquarie Island (Australia) in 2010 (Greenslade, 2018) and has been present on Deception Island since at least 1965, during a 2015 study, two individuals were found at Fumarole Bay in moss and two further specimens were recorded in 2017 at Kroner Lake beach with algae (Enriquez *et al*., 2019).

Hosts

Most collembola feed on fungal hyphae or decaying vegetation and have been reported to control fungal diseases on some plants (Hopkin, 2007). *Protaphorura* species are selective fungus feeders, avoiding some (often toxic) species, and that their selective grazing can affect the outcome of competition between decomposer fungi (Shaw, 2019). Collembola are usually beneficial, however in some cases they feed directly on plant material and cause economic damage. Many species of soil-inhabiting Onychiuridae feed on the roots of plants, including seedlings of field and greenhouse crops, a few species are predators of nematodes (Alford, 2011). *Protaphorura fimata* feeds on the germinating seeds of lettuce (*Lactuca sativa* L.), causing severe stand losses in the northern Salinas Valley of California (Joseph & Bettiga, 2016).

Description

Springtails are small, primitive, wingless invertebrates with mainly biting mouthparts, a sucker-like tube (the collophore) is present on the underside of the first abdominal segment and a forked, tail-like springing organ (the furcula) is present on the fourth segment (Alford, 2011).
As described in Joseph et al (2015): *Protaphorura fimata* is less than 2.5 mm in length; lacks eyes, and pigmentation, and carries 33/022/33333 pseudocelli dorsally on the head and body. Unlike other springtails, *P. fimata* lacks a furcula, and when disturbed does not jump but instead curls up. There are no larval or pupal stages; the newly hatched springtails resemble the adults and reach sexual maturity before they reach maximum size.
Protaphorura fimata is a species within the *P. armata* 'group', and morphological characters to separate species within the group are not reliable (Hopkin, 2007).

Kaprus *et al*. (2016) provides an identification key to the *Protaphorura* in the Eastern Palearctic; Christiansen & Bellinger (1998) provide a key to the collembola of North America from which *P. fimata* can be separated from another; Convey et al. 1999 provide a key to the collembola of sub-Antarctic South Georgia.

Biology

Collembola prefer wet or damp surroundings and are usually are soil and litter dwelling, although some species move actively over the surfaces of bark and flowers in daylight. Collembolans are major components of terrestrial ecosystems (and particularly significant members of the soil communities), constituting a significant proportion of the animal biomass and are thus frequently and easily found (Handschin, 1955).

Protaphorura fimata is a subterranean species which reproduces sexually, their life cycle typically involves fertilisation of the female via a spermatophore delivered by the male. Mating behaviour can be simple or non-existent where the male simply deposits his spermatophore on the substratum at random leaving it to be discovered by the female (Hopkin, 2007). The eggs are deposited in clutches and take a few days or weeks to develop (Hopkin, 2007). After hatching they go through a series of instars, normally five, moulting every few days until they reach adulthood. They may continue to moult throughout their adult lives and can survive for several years in case of some cave dwelling species (Hopkin, 2007).

Dispersal and Detection

Springtails can be carried by the wind and have been recorded at heights of more than 3000 metres, they have been known to colonise remote islands by individuals clinging to driftwood (Hopkin, 2007). Most significantly, they are transported globally by numerous human activities, particularly trade in plants and produce, movement of soil contaminated vehicles or equipment and tourism.

In South Georgia, alien invasive collembolan species numbers increased significantly after the introduction of exotic weeds around dwellings (Convey et al, 1999). Greenslade and Convey (2012) suggested that the importation of root and other vegetables was the route by which these species arrived and that that increased visitation by tourists, research and maintenance personnel seems an obvious cause despite strict quarantine controls imposed on all visitors. In 1994 Pugh highlighted the ineffective control on the import of contaminated equipment or vegetation by the military garrison at King Edward Point, or by the trawlers, yachts and cruise ships that dock.

Deception Island, in the South Shetland Islands is heavily visited by tourists on a daily basis over the summer. Several exotic collembolan species are only found near the geothermal vents (Greenslade *et al.*, 2018), where tourists flock to bath in the warm water.

Use of a Berlese or Tüllgren funnel is the most effective way to collect *Collembola* by extraction of soil, leaf litter or bark. But they may also be collected by hand using a mouth operated aspirator, or hand operated aspirator. Overturning rocks and other objects frequently will expose them, and pitfall traps can be used to capture collembola (Bellinger et al., 2019). Joseph and Bettiga (2015) used beet root (*B. vulgaris*), and potato (*S. tuberosum*) slices to bait capture *P. fimata* in the USA.

Greenslade (2007) provides a comprehensive protocol for surveying collembola, including different collecting methods.

Economic and other Impacts

The invasion and establishment of an exotic species into an ecosystem has the potential to modify interactions between species at all trophic levels. This phenomenon is described as a trophic cascade (references in Greenslade, 2018). The cost in lost ecosystem services that invasive species can pose in native environments has been estimated, in one fresh water environment, to be in the millions of dollars (Walsh et al. 2016).

Exotic invertebrates such as Collembola are a particular threat in the South Atlantic UK Overseas Territories because of the high endemism of the native fauna, in particular, to short-range endemic species by outcompeting them. Another collembolan, *H. purpurescens* is described as "highly invasive" and is thought to have displaced resident species from some habitats on the island of South Georgia (Convey *et al*., 1998.). *Hypogastura viatica* has been introduced to the Antarctic Peninsula and to a number of other sub-Antarctic Islands where it often dominates upper marine littoral habitats.

As well as their impact on biodiversity, there are several re-ports of springtails as pests of crops reducing yields and productivity. *Protaphorura fimata* has been associated with feeding damage to germinating sugar beet seeds and sugar bean and most recently lettuce (references in Joseph et al 2015). Lettuce seedlings in fields with high densities of *P. fimata* show retarded or stunted growth and do not emerge in a synchronous pattern (Joseph et al 2015). The value of lettuce is estimated to be US$1.3 billion in the Salinas Valley (Monterey County Crop report 2012).

7. Acknowledgments

This guide was commissioned by Niall Moore and Jillian Key of the Non-Native Species Secretariat and is based on a series of projects funded by Defra delivered between 2009-2019 aimed at enhancing biosecurity in the UK Overseas Territories. We would like to express our gratitude to for their support and the many individuals in the UKOTs for their help and hospitality.

We would also like to thank Tom Prior (Fera) and Tony Barber for valuable input and reviewing some factsheets, and David Crossley (Fera) for taking most of the Crown copyright and Fera photographs, and for helping to format the final guide.

8. References

Abrahams, P., Beale, T., Cock, M., Corniani, N., Day, R., Godwin, J., Murphy, S., Richards, G. & Vos, J. 2017. Fall Armyworm Status. Impacts and control options in Africa: Preliminary Evidence Note (April 2017). http://www.invasive-species.org/Uploads/InvasiveSpecies/FAW-inception-report.pdf.

Abril, S., Oliveras, J. & Gomez, C. 2007. Foraging activity and dietary spectrum of the Argentine ant (Hymenoptera: Formicidae) in invaded natural areas of the northeast Iberian Peninsula. *Environmental Entomology*, **36** (5): 1166-1173.

Alford, D.V. 2011. *Plant Pests (Collins New Naturalist Library*, *Book 116*). Harper Collins, 400 pp.

André, H.M., Ducarme, X., & Lebrun, P. 2002. Soil biodiversity: myth, reality or conning? *Oikos* **96**:1, 3-24F

Anon. 2017. https://parksaustralia.gov.au/christmas/people-place/red-crabs.html; Retrieved May 2019.

Anon. 1908. The Fruit Fly. (Ceratitis capitata, Wied.). *Bulletin of Miscellaneous Information (Royal Botanic Gardens, Kew), 1908*(1), 6-11. doi:10.2307/4114865

AntWeb. 2019. Species: *Anoplolepis gracilipes*. Online factsheet www.antweb.org/description.do?genus=anoplolepis&species=gracilipes&rank=species. Accessed May 2019.

Armbrecht, I. & Ulloa-Chacón, P. 2003. The little fire ant *Wasmannia auropunctata* (Roger) (Hymenoptera: Formicidae) as a diversity indicator of ants in tropical dry forest fragments of Colombia. *Environmental Entomology*, **32** (3): 542-547.

Balashov, Yu.S. 2007. Harmfulness of parasitic insects and acarines to mammals and birds. *Entomological Review*, **87** (9): 1300-1316.

Barber, A.D. 2008. Key to the identification of British centipedes. Field Study Council Occasional Publications 130: 96 pp.

Barber, A.D. 2009. Centipedes. *Linnean Society Synopses of the British Fauna* (N.S.) **58.** Shrewsbury, Field Studies Council.

Barber, A.D. 2011. An indoor record of *Lithobius melanops* Newport, 1845 from the Falkland Islands. *Bulletin of the British Myriapod & Isopod Group*, **25:** 46-47.

Barnard, P.C. 2011. Order Collembola: The Springtails. In: The Royal Entomological Society Book of British Insects, First Edition. Peter C. Barnard.

Bates, P. 2012. Ticks (Ixodida). *In*: External parasites of small ruminants. A practical guide to their prevention and control. CABI Wallingford. pp 49-63.

Been, T.H., Schomaker, C.H., Seinhorst, J.W. 1995. An advisory system for the management of potato cyst nematodes (Globodera spp.). In: Haverkort AJ, MacKerron DKL, eds. Potato Ecology and Modelling of Crops under Conditions Limiting Growth. The Netherlands: Kluwer Academic Publishers, 305-522.

Beggs, J.R. & Wilson, P.R. 1991. The kaka *Nestor meridionalis*, a New Zealand parrot endangered by introduced wasps and mammals. *Biological Conservation*, **56**: 23-38.

Bellinger, P.F., Christiansen, K.A. & Janssens, F. 2019. Checklist of the Collembola of the World. http://www.collembola.org

Benedict, M.Q., Levine, R.S., Hawley, W.A. & Lounibos, L.P. 2007. Spread of the tiger: global risk of invasion by the mosquito *Aedes albopictus*. *Vector Borne Zoonotic Diseases*, **7** (1): 76-85.

Bentley, M., Hahn, D. & Oi, F. 2016. The thermal breadth of *Nylanderia fulva* (Hymenoptera: Formicidae) is narrower than that of *Solenopsis invicta* at three thermal ramping rates: 1.0, 0.12, and 0.06°C min^{-1}. *Environmental Entomology*, **45** (4): 1058-1062.

Blackmore, C. G. M., Blackmore, M. S. and Grimstad. P. R. 1998. Role of *Anopheles quadrimaculatus* and *Coquillettidia perturbans* (Diptera: Culicidae) in the transmission cycle of Cache Valley virus (Bunyaviridae: Bunyavirus) in the Midwest, U.S.A. Journal of Medical Entomology. **35**(5):660-664.

Block, W. 1980. *Nanorchestes antarcticus* Strandmann (Prostigmata) from Antarctic ice. *Acarologia*, **21** (2): 173-176.

Blommers, L.H.M. 1994. Integrated pest management in European apple orchards. *Annual Review of Entomology*, **39**: 213-241.

Braverman, Y., Marcusfeld, (NIR) O., Adler, H. & Yakobson, B. 1991. Yellow jacket wasps can damage cows' teats by biting. *Medical and Veterinary Entomology*, **5**: 129–130.

Brooks, S. & Nickerson, J.C. 2000. Little fire ant: *Wasmannia auropunctata* (Roger) (Insecta: Hymenoptera: Formicidae) Gainesville, Florida, USA: University of Florida, IFAS extension factsheet.

Brown, P.M.J., Adriaens, T., Bathon, H., Cuppen, J., Goldarazena, A., Hagg, T., Kenis, M., Klausnitzer, B.E.M., Kovar, I., Loomans, A.J.M., Majerus, M.E.N., Nedved, O., Pedersen, J., Rabitsch, W., Roy, H.E., Ternois, V., Zakharov, I.A. & Roy, D.B. 2008. *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. *Biocontrol*, **53** (1): 5-21.

Buczkowski, G., Vargo, E.L. & Silverman, J. 2004. The diminutive supercolony: the Argentine ants of the southeastern United States. *Molecular Ecology*, **13** (8): 2235-2242.

Buren, W. F. 1982. Red imported fire ant now in Puerto Rico. *The Florida Entomologist*, **65**: 188–189.

Buxton, J.H. & Madge, D.S. 1976. The evaluation of the European earwig (*Forficula auricularia*) as a predator of the damson-hop aphid (*Phorodon humuli*). I. Feeding experiments. *Entomologia Experimentalis et Applicata*, **19** (2): 109-114.

CABI. 2018. Invasive species Compendium. Various datasheets downloaded from http://www.cabi.org/isc. CAB International, Wallingford, UK.

CABI. 2019. Invasive species Compendium. Various datasheets downloaded from http://www.cabi.org/isc. CAB International, Wallingford, UK.

CABI. 2019a. *Aphis fabae* (black bean aphid) datasheet. https://www.cabi.org/cpc/datasheet/6196. Accessed 8th May 2019.

Campos, M.R., Biondi, A., Adiga A, Guedes, R.N.C. & Desneux, N. 2017. From the western Palaearctic region to beyond: *Tuta absoluta*, 10 years after invading Europe. *Journal of Pest Science*, **90**: 787–796.

Caparros Megido, R., Haubruge, E & F.J. Verheggen. 2012. First evidence of deuterotokous parthenogenesis in the tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *Journal of Pest Science*, **85** (4): 409-412.

Capinera, J.L. 2016. European earwig, *Forficula auricularia* Linnaeus (Dermaptera: Forficulidae). Gainesville, Florida, USA: University of Florida, IFAS extension, 5 pp. [Publication #EENY483 (IN875)].

Capinera, J.L. 2017. Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) (Insecta: Lepidoptera: Noctuidae). Gainesville, Florida, USA: University of Florida, IFAS extension, 6 pp. [Publication #EENY098].

Carpenter, J.S., LaCasse, W.J. 1955. Mosquitoes of North America (North of Mexico). Berkeley: University of California Press.

Carpintero, S., Reyes-López, J. & Arias de Reyna, L. 2005. Impact of Argentine ants (*Linepithema humile*) on an arboreal ant community in Doñana National Park, Spain. *Biodiversity and Conservation*, **14** (1): 151-163.

Carroll, L.E., Norrbom, A.L., Dallwitz, M.J., & F.C. Thompson. 2004. Pest fruit flies of the world – larvae. Version: 9th April 2019. delta-intkey.com

Casmuz, A., Juarez, M. L., Socıas, M.G., Murua, M. G., Prieto, S., Medina, S., Willink, E. & Gastaminza, G. 2010. Revision delos hospederos del gusano cogollero del maız, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Revista de la Socie- dad Entomologica Argentina*, **69**: 209–231.

Cassagne, N., Gers, C., Gauquela, T. 2003. Relationships between Collembola, soil chemistry and humus types in forest stands (France). Biology and Fertility of Soils, **37**: 355-561.

CDC (2007) West Nile Virus Activity https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5726a2.htm

CDC. 2012. Anopheles mosquitoes. https://www.cdc.gov/malaria/about/biology/#tabs-1-5

Chan, C.K., Forbes. A.R., Raworth, D.A. 1991 Aphid-transmitted viruses and their vectors of the world. Agriculture Canada Research Branch Technical Bulletin 1991-3E, 216pp.

Chant, D.A. & McLeod, J.H. 1952 Effects of certain climactic factors on the daily abundance of the European earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae), in Vancouver, British Columbia. *The Canadian Entomologist*, **84** (6): 174-180.

Chapin, E.A. 1965. Coccinellidae. *Insects of Micronesia*. Coleoptera, 189-254. Honolulu, Hawaii: Bernice P. Bishop Musuem.

Chapin, J.B. & Brou, V.A. 1991. *Harmonia axyridis* (Pallas), the third species of the genus to be found in the United States (Coleoptera: Coccinellidae). *Proceedings of the Entomological Society Washington*, **93**: 630-635.

Chifflet, L., Guzma, N.V., Rey, O., Confalonieri, V. A. & Calcaterra, L. A. 2018. Southern expansion of the invasive ant *Wasmannia auropunctata* within its native range and its relation with clonality and human activity. PLoS ONE, **13** (11): e0206602. https://doi.org/10.

Chinery, M. 1973. *A Field Guide to the Insects of Britain and Northern Europe*. Collins, St. James's Place, London, 352 pp.

Christiansen, K. & Bellinger, P. 1998. The *Collembola of North America North of the Rio Grande, A taxonomic analysis*. Grinnell College, Iowa, 1520 pp.

Cloudsley-Thompson, J.L. 1945. Behaviour of the Common Centipede *Lithobius forficatus. Nature*, **156**: 537–538.

Coleman, D.C., Crossley, D.A., & Hendrix, P.F. 2004. Secondary Production: Activities of Heterotrophic Organisms—The Soil Fauna. *In: Fundamentals of Soil Ecology* (Second Edition).

Collingwood, C.A. 1979. The Formicidae (Hymenoptera) of Fennoscandia and Denmark. *Fauna Entomologica Scandinavica*, **8**: 1-17.

Convey, P., Greenslade, P., Arnold, & Block, W. 1999. Collembola of sub-Atlantic South Georgia. *Polar Biol* **22:** 1. https://doi.org/10.1007/s003000050383

Crumb, S.E., Eide, P.M. & Bonn, A.E. 1941. The European Earwig. Technical Bulletin. United States Department of Agriculture, 766. Washington, D.C., 76 pp.

Davies, R. 2005. Predation and the profitability of grouse moors. *British Wildlife*, **16**: 339-347.

Davis, N., O'Dowd, D., Green, P., MacNally, R., 15 July 2008; "Effects of an Alien Ant Invasion on Abundance, Behaviour, and Reproductive Success of Endemic Island Birds" Conservation Biology Journal; Society for Conservation Biology.

Davis, L.R., Vander Meer, R.K. & Porter, S.D. 2001. Red imported fire ants expand their range across the West Indies. *The Florida Entomologist*, **84** (4): 735.

Davis, N., O'Dowd, D., Green, P. & MacNally, R. 2008. Effects of an Alien Ant Invasion on Abundance, Behaviour, and Reproductive Success of Endemic Island Birds. Conservation Biology, **22**(5) pp. 1165-76.

Deharveng, L. 2004. Recent advances in Collembola systematics. Pedobiologia, **48**: 415-433.

Dejean, A., Le Breton, J., Suzzoni, J.P., Orivel, J. & Saux-Moreau, C. 2005. Influence of interspecific competition on the recruitment behaviour and liquid food transport in the tramp ant species *Pheidole megacepahala*. *Naturwissenschaften*, **92** (7): 324-327.

De Jong, Y. et al. 2014. Fauna Europaea - all European animal species on the web. *Biodiversity Data Journal* 2: e4034. doi: 10.3897/BDJ.2.e4034.

De Meyer, M. 1998. Systematic revision of the subgenus Ceratitis(Ceratalaspis) (Diptera, Tephritidae). Bulletin of entomological Research 88: 257-290.

De Meyer, M., Quilici, S. Franck, A., Chadhouliati, A.C., Issimaila, M.A., Youssoufa, M.A. Barbet, A., Attié, M. & White, I.M. 2012. Frugivorous fruit flies (Diptera, Tephritidae, Dacini) of the Comoro Archipelago. *African Invertebrates*, **53**: 69-77.

De Villiers, M., Kriticos D.J. & Veldtman R. 2017. Including irrigation in niche modelling of the invasive wasp *Vespula germanica* (Fabricius) improves model fit to predict potential for further spread. PLoS ONE **12** (7): e0181397. https://doi.org/10.1371/journal.pone.0181397

Desneux, N., Luna, M.G., Guillemaud, T. & Urbaneja A. 2011. The invasive South American tomato pinworm, Tuta absoluta continues to spread in Afro-Eurasia and beyond: the new threat to tomato world production. *Journal of Pest Science*, 84: 403-408.

Deyrup, M., Davis, L.& Buckner, S. 1998. Composition of the Ant Fauna of Three Bahamian Islands (PDF). San Salvador: Proceedings of the 7th Symposium on the Natural History of the Bahamas. p. 27. *ISBN 978-0-935909-66-1*.

Deyrup, M., Davis, L. & Cover, S. 2000. Exotic ants in Florida. *Transactions of the American Entomological Society*, **126**: 293-326.

Dobzhansky, T. 1933. Geographical variation in ladybeetles. *The American Naturalist*, **67**: 97-126.

Douglas, A. E. 1997. Provenance, experience and plant utilisation by the polyphagous aphid, *Aphis fabae*. *Entomologia experimentalis et Applicata*, **83**: 161-170.

Drees, B.M., Collins, H., Williams, D.F. & Bhatkar A. 2002. Considerations for planning, implementing, and evaluating a spot-eradication program for imported fire ants. Fire Ant Plan Fact Sheet #30, http://fireant.tamu.edu/materials/index.html.

Drees, B.M. & Lard, C.F. 2006. Imported fire ant: economic impacts justifying integrated pest management programs. In: *Proceedings of the XV Congress of the International Union for the study of social insects*, Washington, DC, 30 July – 4 August 2006.

Dromph, K.M., Borgen, A. 2001. Reduction of viability of soil borne inoculum of common bunt (*Tilletia tritici*) by collembolans. Soil Biology and Biochemistry, **33**: 1791-1795.

Eason, E. H. 1969. On certain characters used to separate species and sub-species of Lithobiidae. *Bull. Mus. Hist. Nat. Paris*, **41** (2): 58-60

ECDC. 2012. European Centre for Disease Prevention and Control. Guidelines for the surveillance of invasive mosquitoes in Europe. Stockholm: ECDC; 2012.

ECDC. 2016a. European Centre for Disease Prevention and Control. *Aedes aegypti* – Factsheet for experts. https://ecdc.europa.eu/en/disease-vectors/facts/mosquito-factsheets/aedes-aegypti Accessed March 2019.

ECDC. 2016b. European Centre for Disease Prevention and Control. *Aedes albopictus* – Factsheet for experts. https://ecdc.europa.eu/en/disease-vectors/facts/mosquito-factsheets/aedes-albopictus. Accessed 21st February 2019.

Ekesi, S., Billah, M.K., Nderitu, P.W., Lux, S.A. & Rwomushana, I. 2009. Evidence for competitive displacement of *Ceratitis cosyra* by the invasive fruit fly *Bactrocera invadens* (Diptera: Tephritidae) on mango and mechanisms contributing to the displacement. *Journal of Economic Entomology*, **102**: 981-991.

Elston, D.A., Phillips, M.S., Trudgill, D.L. 1991. The relationship between initial population density of potato cyst nematode *Globodera pallida* and the yield of partially resistant potatoes. Revue de Nematologie, **14**(2):221-229.

Enriquez, N., Pertierra, L. R., Tejedo, P., Benayas, J., Greenslade, P. & Lucianez, M.L.2019. The importance of long-term surveys on species introductions in Maritime Antarctica: first detection of *Ceratophysella succinea* (Collembola: Hypogastruridae). *Polar Biology* **1-5**. 10.1007/s00300-019-02490-8.

Entomological Society of America (ESA). 2016. Common names of Insects Database. http://www.entsoc.org/common-names.

EPPO. 2013. Bulletin OEPP/EPPO Bulletin PM 7/40 (3) *Globodera rostochiensis* and *Globodera pallida* Bulletin OEPP/EPPO **43** (1): 119-138.

EPPO. 2015. PM 7/124 (1) *Spodoptera littoralis*, *Spodoptera litura*, *Spodoptera frugiperda*, *Spodoptera eridania*. *Bulletin OEPP/EPPO*, **45**: 410–444. https://doi.org/10.1111/epp.12258/epd.

EPPO. 2017. Bulletin OEPP/EPPO Bulletin PM 7/40 (4) Globodera rostochiensis and Globodera pallida Bulletin OEPP/EPPO **47** (2):174-197.

EPPO. 2019. *Spodoptera frugiperda*. Data Sheets on Quarantine Pests. EPPO global Database. https://gd.eppo.int/taxon/LAPHFR. Accessed March 2019.

EPPO. 2019. *Tuta absoluta* https://gd.eppo.int/taxon/GNORAB. EPPO Global Database. Accessed March 2019.

Eritja, R., Escosa, R., Lucientes, J., Marquès, E., Molina, R., Roiz, D. & Ruiz S. 2005. Worldwide invasion of vector mosquitoes: present European distribution and challenges for Spain. *Biological Invasions* **7**: 87-97.

Evans, A. 1938. *Mosquitoes of the Ethiopian Region*. London: Oxford University Press.

Evans, K. 1970. Longevity of males and fertilization of females of *Heterodera rostochiensis*. Nematologica, **16**:369-374.

Farajollahi, A. & Price D.C. 2013. A rapid identification guide for larvae of the most common North American container inhabiting *Aedes* species of medical importance. *Journal of the American Mosquito Control Association* **29**(3): 203-221.

Ferracini, C., Ingegno, B.L., Navone, P., Ferrari, E., Mosti, M., Tavella, L. & Alma, A. 2012. Adaptation of indigenous larval parasitoids to Tuta absoluta (Lepidoptera: Gelechiidae) in Italy. *Journal of Economic Entomology* **105**:1311–9.

Fiera, C. 2009. Biodiversity of Collembola in urban soils and their use as bioindicators for pollution Pesq. agropec. bras., Brasília **44 (**8): 868-873.

Fischer, M. K., Völkl, W. and Hoffmann, K. H. 2005. Honeydew production and honeydew sugar composition of polyphagous black bean aphid, *Aphis fabae* (Hemiptera: Aphididae) on various host plants and implications for ant-attendance. *European Journal of Entomology*, **102**: 155-160.

Fitzsimons, J.M. 1971a. Temperature and three species of Antarctic arthropods. Pacific Insects Monograph, **25**: 127-135.

Fitzsimons, J.M. 1971b. On the food habits of certain Antarctic arthropods from coastal Victoria Land and adjacent islands. *Pacific Insects Monograph*, **25**:121-125.

Foldvari, G. 2016. Life cycle and ecology of *Ixodes ricinus*: the roots of public health importance. *Ecology and control of vector-borne diseases*, **4**: 31-40.

Foster, E. 1908. The introduction of *Iridomyrmex humilis* (Mayr) into New Orleans. Journal of Economic Entomology **1**: 289-293.

Foster, W.A. & Walker E.D. 2002. Mosquitoes (Culicidae). *In* Mullen, G., Durden, L. (Eds.) *Medical and Veterinary Entomology* (p 203-262). Academic press, San Diego, CA. 597 pp.

Foster, W.A. & Walker, E.D. 2009. Mosquitoes (Culicidae). *In* Mullen, G, Durden, L. (Eds.) Medical and veterinary entomology. 2nd Ed. (pp. 207-259). Academic Press, Burlington, MA. 637 pp.

Franco, J. 1979. Effect of temperature on hatching and multiplication of potato cyst-nematodes. Nematologica, **25**(2):237-244.

Gabrys, B. 2008 Cabbage Aphid, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) In: Encyclopedia of Entomology. Ed J.L. Capinera.

Garros, C., Ngungi, N., Githeko, A.E., Tuno, N. & Yan, G. 2008. Gut content identification of larvae of the *Anopheles gambiae* complex in western Kenya using a barcoding approach. Molecular Ecology Resources 8: 512-518.

Gatt, P., Deeming, J.C. & Schaffner, F. 2009. First record of *Aedes* (*Stegomyia*) *albopictus* (Skuse) (Diptera: Culicidae) in Malta. *European Mosquito Bulletin* **27**: 56-64.

Gill, H.K., Garg, H., Gillett-Kaufman, J.L. 2013. Cabbage Aphid, *Brevicoryne brassicae* (L). University of Florida factsheet.

Gillies, M.T, de Meillon, B. 1968. The Anophelinae of Africa south of the Sahara (Ethiopian Zoogeographical Region). Publications of the South African Institute for Medical Research 54: 1-343.

Giraud, T., Pedersen, J.S., & Keller, L. 2002. Evolution of supercolonies: the Argentine ants of southern Europe. *Proceedings of the National Academy of Sciences of the United States of America*, **99**(9):6075-6079.

GISD. 2013. Global Invasive Species Database. 100 of the World's worst invasive alien species. http://www.iucngisd.org/gisd/100_worst.php. Accessed 21st February 2019.

GISD. 2019a. Species profile: *Wasmannia auropunctata*. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=58 on 04-03-2019.

GISD. 2019b. Species profile: *Vespula germanica*. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=896 on 19-03-2019.

GISD. 2019c. Species profile: *Anoplolepis gracilipes*. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=110 on 28-05-2019.

Giska, I., & Babik, W.A. 2016. The Centipede *Lithobius forficatus* is a complex of cryptic species. Conference Proceedings. https://pdfs.semanticscholar.org/78fb/0685ecf554097d9f83f4da988dca15b3739e.pdf?_ga=2.131276111.1935266729.1559633601-737430368.1559633601

Gobin, B., Peusens, G., Moerkens, R. & Leirs, H. 2008. Understanding earwig phenology in top fruit orchards. In: Ecofruit. 13th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing. *Proceedings of the conference, Weinsberg, Germany, 18-20 February 2008* [ed. by Fördergemeinschaft Ökologischer Obstbau e. V.]. Weinsberg, Germany: Fördergemeinschaft Ökologischer Obstbau e.V. (FÖKO), 208-212.

Goergen, G., Kumar, L. P. Sankung, S. B., Togola, A. & Tamò, M. 2016. First Report of Outbreaks of the Fall Armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), a New Alien Invasive Pest in West and Central Africa. *PLOS ONE*, **11**(10): e0165632.

Gotzek, D., Brady, S.G., Kallal, R.J. & LaPolla, J.S. 2012. The importance of using multiple approaches for identifying emerging invasive species: The case if the Raspberry crazy ant in the United States. *PLoS ONE*, **7** e45314.

Gray, I., Wilkins, V., Pryce, D., Fowler, L., Key, R.S., Mendel, H., Jervois, M., Hochkirch, A., Cairns-Wicks, R., Dutton, A-J. & Malan, L. 2018. The status of the invertebrate fauna on the South Atlantic island of St Helena: problems, analysis, and recommendations. Biodiversity and Conservation. Online version https://doi.org/10.1007/s10531-018-1653-4

Green, C.D. & Miller, L.I. 1969. Cyst nematodes: attraction of males to females. Report of Rothamsted Experimental Station for 1968. Part 1. Rothamsted, UK: Rothamsted Experimental Station, 153-15.

Greenfield, B.P.J. 2011 Environmental parameters affecting ticks (*Ixodes ricinus*) distribution during the summer season in Richmond Park, London. *Bioscience Horizons: The International Journal of Student Research*, **4**(2,1): 140-148.

Greenslade, P. 2018. Why are there so many exotic springtails in Australia? A review. *Soil Organisms* **90** (3), pp 141-156

Greenslade, P. & Convey, P. 2012. Exotic Collembola on subantarctic islands: Pathways, origins and biology. *Biological Invasions*. **14**. 405-417. 10.1007/s10530-011-0086-8.

Grout, T.G.& K.C. Stoltz. 2007. Developmental rates at constant temperatures of three economically important Ceratitis spp. (Diptera: Tephritidae) from southern Africa. *Environmental Entomology* **36**: 1310-1317.

Guillemaud, T., Blin A., Goff I.L., Desneux N., Reyes M., Tabone E., Tsagkarakou A., Nino L., Lombaert E. 2015. The tomato borer, *Tuta absoluta*, invading the Mediterranean Basin, originate from a single introduction from Central Chile. *Scientific Reports* **5**, 8371.

Gunawardana, D. & Sarnat, E. 2007. Pacific invasive ants taxonomy workshop: Workshop manual. Suva Fiji 26th-28th June 2007. http://www.issg.org/cii/Electronic%20references/pii/project_docs/papp/pacific_ants_taxonomy_workshop_2009.pdf.

Gutrich, J.J., VanGelder, E. & Loope, L. 2007. Potential economic impact of introduction and spread of the red imported fire ant, *Solenopsis invicta* in Hawaii. *Environmental Science and Policy*, **10**, 685-696.

Hafez, M. 1961. Seasonal fluctuation of population density of the cabbage aphid *Brevicoryne brassicae* (L.) in the Netherlands and the role of its parasite Aphidius (Diaeretiella) rapae (Cutis). T. Pl-Ziekten, **67**: 445-548.

Handschin, E. 1955. Considérations sur la position systématique des Collemboles., Mémoires de la Société Royale d'Entomologie de Belgique, Tome Vingt-Septième, Volume Jublaire, 1955, p.40-53.

Harmon, K. 2009. Honeybees face new threat in Texas: “Crazy” ants. Scientific American News Blog. Accessed March 2019.

Harris, R. (n.d.). Invasive ant risk assessment: *Monomorium destructor*. Landcare Research. http://hbs.bishopmuseum.org/fiji/pdf/harris-mono.pdf. Accessed February 2019.

Harris, R., Abbott, K., Barton, K., Berry, J., Don, W., Gunawardana, D., Lester, P., Rees, J., Stanley, M. Sutherland, A. & Toft, R. 2005. Invasive ant pest risk assessment project for Biosecurity New

Zealand. Series of unpublished Landcare Research contract reports to Biosecurity New Zealand. BA H/35/2004-1.

He, X.Z., Wang, Q. & Xu, J. 2008. European earwig as a potential biological control agent of apple leaf-curling midge. New Zealand Plant Protection, 61 (The New Zealand Plant Protection Society 61st Annual Conference, Copthorne Hotel, Paihia, Bay of Islands, New Zealand, 12-14 August 2008), 343-349. http://www.nzpps.org/journal.php

Henderson, G. 2001. Practical considerations of the Formosan subterranean termite in Louisiana: A 50-year-old problem. *Sociobiology*, **37**:281-292.

Hickerson, C. A., Anthony, C. D. & Walton, B.M. 2005. Edge effects and intraguild predation in native and introduced centipedes: evidence from the field and from laboratory microcosms. *Oecologia*, **146** (1): 110-119.

Hill, S.K., Baldwin, R.W., Pereira, R.M. & Koehler, P.G. 2016. Tawny Crazy Ant. Available online: http://edis.ifas.ufl.edu/pdffiles/IN/IN107600.pdf.

Hines, R.L., Hutchison, W.D. 2013. Cabbage aphids. VegEdge, vegetable IPM resource for the Midwest. University of Minnesota, Minneapolis, MN. (2 October 2013).

Hoffman, B. 2019a. Global Invasive Species Database Species profile: *Monomorium destructor*. http://www.iucngisd.org/gisd/species.php?sc=960 on 13-02-2019.

Hoffmann, B. 2019b. Global Invasive Species Database Species profile: *Pheidole megacephala*. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=132 on 18-03-2019.

Hoffmann, B.D., Andersen, A.N. & G.J.E Hill. 1999. Impact of an introduced ant on native rain forest invertebrates: *Pheidole megacephala* in monsoonal Australia. *Oecologia*, **120**: 595-604.

Holoway, D.A., Lach, L., Suarez, A.V., Tsutsui, N. D., Case, T. J. 2002. The causes and consequences of ant invasions. *Annual Review of Ecology and Systematics* **33**: 181–233.

Hominick, W.M. 1986. Photoperiod and diapause in the potato cyst nematode *Globodera rostochiensis*. Nematologica, **32**:408-418.

Honório, N.A, Codeço, C.T, Alves, F.C, Magahães, M.A.F.M. & Lourenço-de-Oliveira, R. 2009. Temporal distribution of *Aedes aegypti* in different districts of Rio De Janeiro, Brazil, measured by two types of Traps. *Journal of Medical Entomology* **46**(5): 1001-1014.

Hopkin, S.P. (2007) A key to the Collembola (Springtails) of Britain and Ireland. Field Study Council, Preston, Montford (AIDGAP); 245pp.

Holway, D.A., Lach, L., Suarez, A.V., Tsutsui, N.D. & Case, T.J. 2002. The causes and consequences of ant invasions. *Annual Review of Ecology and Systematics*, **33**:181-233.

Hoskin, C., & Lach, L. 2015. Too much to lose: Yellow crazy ants in the wet tropics. Wildlife Australia **52**:3, pp. 37-41http://www.wettropics.gov.au/site/user-assets/docs/yellow-crazy-ants-lach--hoskin-spring-2015.pdf; Retrieved May 2019.

Hukusima, S. & Ohwaki, T. 1972 Further notes on feeding biology of *Harmonia axyridis* (Coleoptera: Coccinellidae). *Research Bulletin of the Faculty of Agriculture, Gifu University* **33**: 75-82.

IAEA. 2013. Trapping manual for area-wide fruit fly programmes. IAEA, Vienna, 46pp.

ISSG. 2014. Global Invasive Species Database (GISD). Invasive Species Specialist Group of the IUCN Species Survival Commission. http://www.issg.org/database/welcome/.

Imenes, S.D.L., Uchôa-Fernandes, M.A., Campos, T.B. & Takematsu, A.P. 1990. Aspectos biológicos e comportamentais da trata do tomateiro Scrobipalpula absoluta (Meyrick, 1917), (Lepidoptera-Gelechiidae). *Arquivos do Instituto Biológico, Sao Paulo*, **57**(1/2):63-68.

Janion-Scheepers, C. 2019. Collembola of South Africa. URL: www.collembola.co.za (accessed on 1/06/2019).

Jeffries, D.L., Chapman, J., Roy, H.E., Humphries, S., Harrington, R., Brown, P.M.J., Handley, L.J.L. 2013. Characteristics and drivers of high-altitude ladybird flight: insights from vertical-looking entomological radar. *PLoS ONE*, **8**(12):82278. http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0082278

Jongejan, E. & Uilenberg, G. 1994. Ticks and control methods. *Scientific and Technical Review of the Office International des Epizooties*, **13**(4): 1201-1226.

Joseph, S. & Bettiga, C. 2016. Captures of *Protaphorura fimata* (Collembola: Poduromorpha:Onychiuridae) on Beet and Potato Baits in the Salinas Valley of California. *Journal of Entomological Science.* **51**. 79-86. 10.18474/JES15-26.1.

Joseph, S.V., Bettiga, C., Ramirez, C. & Soto-Adames, F. N. 2015. Evidence of *Protaphorura fimata* (Collembola: Poduromorpha: Onychiuridae) feeding on germinating lettuce in the Salinas Valley of California. *J Econ Entomol*; **108**(1):228-36. doi: 10.1093/jee/tou021. Epub 2015 Jan 24.

Jung, J., Jung, S., Ahmed, M., Cho, B. & Lee, W. (2017). Invasion risk of the yellow crazy ant (*Anoplolepis gracilipes*) under the RCP 8.5 climate change scenario in South Korea. *Journal of Asia-Pacific Biodiversity*. **10** DOI: 10.1016/j.japb.2017.08.004.

Kairo, M. T. K., Pollard, G. V., Peterkin, D. D. & Lopez, V. F. 2000. Biological control of the hibiscus mealybug, *Maconellicoccus hirsutus* in the Caribbean. *Integrated Pest Management Reviews*, **5**: 241–254.

Kaprus, I., Weiner, W. & Pasnik, G.2016. Collembola of the genus *Protaphorura* Absolon, 1901 (Onychiuridae) in the Eastern Palearctic: morphology, distribution, identification key. *ZooKeys* **620**: 119-150. https://doi.org/10.3897/zookeys.620.9372

Kessing, J.L.M., Mau, R.F.L. 1991. Cabbage aphid, *Brevicoryne brassicae* (Linnaeus). Crop Knowledge Master. Department of Entomology, Honolulu, Hawaii. (2 October 2013).

Kettle, D.S. 1990. Ixodida – Ixodidae (Hard Ticks). In: Medical and Veterinary Entomology. CABI Wallingford. Pp 423-448.

Kirschenbaum, R. and J. K. Grace. 2008. Agonistic responses of the tramp ants *Anoplolepis gracilipes*, *Pheidole megacephala*, *Linepithema humile*, and *Wasmannia auropunctata* (Hymenoptera: Formicidae). Sociobiology **51**(3): 673-84.

Koch, R.L. 2003. The multicoloured Asian lady beetle, *Harmonia axyridis*: A review of its biology, uses in biological control, and non-target impacts. *Journal of Insect Science* **3** (32): 1-16.

Koch, R.L., Venette, R.C. & Hutchison, W.D. 2006. Invasions by *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in the Western Hemisphere: implications for South America. *Neotropical Entomology*, **35**(4):421-434. http://www.scielo.br/ne

Konate, L., Faye, O., Gaye, O., Diouf, M. & Diop, A. 1999. Observations on the feeding patterns and the alternative hosts selection of the malaria vectors in Senegal. *Parasite*, **6**(3): 257-267.

Korycinska, A. & H. Moran. 2009. Plant Pest Notice: South American tomato moth, *Tuta absoluta* (No. 56). pp. 1-4. Department for Environment, Food and Rural Affairs, Food and Environment Research Agency.

Kirschenbaum, R. and J. K. Grace. 2008. Agonistic responses of the tramp ants *Anoplolepis gracilipes*, *Pheidole megacephala*, *Linepithema humile*, and *Wasmannia auropunctata* (Hymenoptera: Formicidae). Sociobiology **51**(3), 673-84.

Kuznetsov, V.N. 1997. Ladybirds of Russian Far East. Gainseville, FL: Memoir Seis Editor, CSE

La Fage J. 1987. Practical considerations of the Formosan subterranean termite in Louisiana: a 30-year-old problem. In: Tamashiro M, Su NY, eds. *Biology and control of the Formosan subterranean termite*. Honolulu, USA: College of Tropical Agriculture Human Resources, University of Hawaii, 37-42.

Lai, P. Y., Tamashiro, M., Yates, J. R., Su, N. Y, Fujii, J. K. & Ebesu, R. H. 1983. Living plants in Hawaii attacked by *Coptotermes formosanus*. *Proceedings of the Hawaiian Entomological Society*, **24** (2/3): 283-286.

Lamb, R.J. 1976. Parental behaviour in the Dermaptera with special reference to *Forficula auricularia* (Dermaptera: Forficulidae). *Canadian Entomologist*, **108**(6):609-619.

Lawrence, R.F. 1956. Chilopoda of Tristan da Cunha. *Results of the Norwegian Scientific Expedition to Tristan da Cunha*, 39, 1–13.

LeBrun, E.G., Abbott, J. & Gilbert, L.E. 2013. Imported crazy ant displaces imported fire ant, reduces and homogenizes grassland ant and arthropod assemblages. *Biological Invasions*, **15**: 2429-2442.

Leinaas, H.P., Bengtsson, J., Janion-Scheepers, C., & Chown, S. L. 2015. Indirect effects of habitat disturbance on invasion: nutritious litter from a grazing resistant plant favors alien over native Collembola. *Ecol Evol.* **5**(16): 3462–3471.

Lewis, J.G.E. 1965. The Food and Reproductive Cycles of the Centipedes *Lithobius variegatus* and *Lithobius forficatus* in a Yorkshire Woodland, *Proc. Zool. Soc.* **144**: 269-83

Li, B. N., Ma, J., Hu, X. N., Liu, H. J., & Zhang, R. J. 2009. Potential geographical distributions of the fruit flies *Ceratitis capitata*, *Ceratitis cosyra*, and *Ceratitis rosa* in China. *Journal of Economic Entomology*, 102, 1781– 1790. https://doi.org/10.1603/029.102.0508

Lindsay, K.L. 1972. *Nanorchestes antarcticus* Strandmann; A taxonomic description of the instars. *Acarologia*, **XIII**: 594-606.

Logan, D.P., Maher, B.J. & Connolly, P.G. 2011. Increased numbers of earwigs (*Forficula auricularia*) in kiwifruit orchards are associated with fewer broad-spectrum sprays. New Zealand Plant Protection [*New Zealand Plant Protection Society's Annual Conference, Rotorua, New Zealand, 9-11 August 2011*.], **64**:49-54. http://www.nzpps.org/journal/abstract.php?paper=640490

Lux, S. A., Ekesi, S., Dimbi, S., Mohamed, S., & Billah, M. 2003. Mango infesting fruit flies in Africa. Perspectives and limitations of biological approaches to their management. In P. Neuenschwander, C. Borgemeister & J. Langewald (Eds.), Biological control in integrated pest management systems in Africa (pp. 277– 293). Wallingford, UK: CABI.

MacGowan, J.A. 2016. Ants (Formicidae) of the south eastern United States. Mississippi State University Fact Sheet.

MacGowan, J. & Layton, B. 2010. The invasive Rasberry crazy ant, *Nylanderia* sp. Near *pubens* (Hymenoptera: Formicidae), reported from Mississippi. *Midsouth Entomol*. **3**: 44-47.

Maczey, N., Edgington, S., Moore, D. & Haye, T. 2016. Biology and host range testing of *Triarthria setipennis* and *Ocytata pallipes* (Diptera: Tachinidae) for the control of the European earwig (*Forficula auricularia*). *Biocontrol Science and Technology*, **26** (4): 447-461.

Magnarelli, L.A. 1975. Life history and physiological age studies of *Anopheles quadrimaculatus* Say in central New York State. *Proceedings of the New Jersey Mosquito Control Association*, 83-89.

Maher, B.J. & Logan, D.P. 2007. European earwigs, *Forficula auricularia*, and predation of scale insects in organic and conventionally managed kiwifruit. New Zealand Plant Protection [*The New Zealand Plant Protection Society 60th Annual Conference, The War Memorial and Conference Center, Napier, New Zealand, 14-16 August 2007.*], **60**:249-253. http://www.nzpps.org/journal.php

Majerus, M., Strawson, V. & Roy, H. 2006. The potential impacts of the arrival of the Harlequin ladybird, *Harmonia axyridis* (Pallas) Coleoptera: Coccinellidae, in Britain. *Ecological* Entomology, **31** (3): 207-215.

Malumphy, C., Hamilton, M.A., Manco, B.N., Green, W.C., Sanchez, M.D., Corcoran, M. & Salamanca, E. 2012. *Toumeyella parvicornis* (Hemiptera: Coccidae) Causing Severe Declie of *Pinus caribaea* var. *bahamensis* in the Turks and Caicos Islands. *Florida Entomologist*, **95** (1): 113-119.

Manrakhan, A. & Lux, S.A. 2006. Contribution of natural food sources to reproductive behavior, fecundity and longevity of *Ceratitis cosyra, C. fasciventris* and *C. capitata* (Diptera: Tephritidae). *Bulletin of Entomological Research*, **96**: 259-268.

Manrakhan, A., Daneel, J-H., Beck, R., Virgilio, M., Meganck, K. & De Meyer, M. 2017. Efficacy of trapping systems for monitoring of Afrotropical fruit flies. *Journal of applied Entomology* doi: 10.1111/jen.12373.

Mansour, R., Brévault, T., Chailleux, A., Cherif, A., Grissa-Lebdi, K., Haddi, K., Samira, M. & Robert S. 2018. Occurrence, biology, natural enemies and management of *Tuta absoluta* in Africa. *Entomologia Generalis*, **38** (2): 83–112.

McGlynn, T.P. 1999. The Worldwide Transfer of Ants: Geographical Distribution and Ecological Invasions, *Journal of Biogeography*, **26** (3): 535-548.

Marshall, D.J. & Pugh, F.L.S. 1996. Origin of the inland Acari of Continental Antarctica, with particular reference to Dronning Maud Land. *Zoological Journal of the Linnean Society*, **118**: 101-118.

Medlock, J.M., Hansford, K.M., Bormane, A., Derdakova, M., Estrada-Pena, A., George, J., Golovljova, I., Jaenson, T.G.T., Jenson, J., Jenson, P.M., Kazimirova, M., Oteo, J.A., Papa, A., Pfister, K., Plantard, O., Randolph, S.E., Rizzoli, A., Santos-Silva, M.M., Sprong, H., Vial, L., Hendrickx, G., Zeller, H. & Bortel, W. 2013. Driving forces for changes in geographical distribution of *Ixodes ricinus* ticks in Europe. *Parasites & Vectors*, **6**: 1-11.

Meijerink, J., Braks, M., Brack, A., Adam, W. & Dekker, T. 2000. Identification of olfactory stimulants for Anopheles gambiae from human sweat samples. *Journal of Chemical Ecology*, **26**(6): 1367-1382.

Meyers, J.M. 2008. Identification, distribution and control of an invasive pest ant, *Paratrechina* sp. (Hymenoptera: Formicidae), in Texas. PhD. Thesis, Texas A&M University College Station, TX, USA, 2008.

Midega, J.T, Mbogo, C.M, Mwnambi, H., Wilson, M.D., Ojwang, G., Mwangang, J.M., Nzovu, J.G, Githure JI, Yan G, Beier JC. 2007. Estimating dispersal and survival of Anopheles gambiae and Anopheles funestus along the Kenyan coast by using mark-release-recapture methods. J Med Entomol. 44(6):923-9

Miller, G.L. & Stoetzel, M.B. 1997. Aphids associated with chrysanthemums in the United States. *Florida Entomologist*, **80** (2): 218-239.

Monterey County Crop report. 2012. Office of Agricultural commissioner- Monterey County, California. (http://ag.co.monterey.ca.us/assets/resources/assets/334/CropReport_

Moore, C.G. 1999. *Aedes albopictus* in the United States: Current status and prospects for further spread. *Journal of the American Mosquito Control Association*, **15** (2): 221-227.

Morrison, L.W., Porteer, S.D., Daniels E., Korzukhin, M.D. 2004. Potential global range expansion of the invasive fire ant, *Solenopsis invicta*. *Biological Invasions*, **6**: 183-191.

Natwick, E.T. 2009. Cole crops: cabbage aphid. UC Pest Management Guidelines. University of California Agriculture & Natural Resources. (2 October 2013)

Nayar, J.K., Sauerman Jr, D.M. 1975. Physiological basis of host susceptibility of Florida mosquitoes to *Dirofilaria immitis*. *Journal of Insect Physiology*, **21**: 1965-1975.

Nchinda, T. 1998. "Centers for Disease Control and Prevention" (On-line). Accessed 12/15/04 at

http://www.cdc.gov/ncidod/eid/vol4no3/nchinda.htm.

Ness, J.H. & Bronstein, J.L. 2004. The effects of invasive ants on prospective ant mutualists. *Biological Invasions*, **6**: 445-461.

Newell, W. & Barber, T.C. 1913. The Argentine Ant. U.S Dept. Agric. *Bureau of Entomology Bulletin*, 98pp.

Nottingham, S.F. & Hardie, J. 1989. Migratory and targeted flight in seasonal forms of the black bean aphid, *Aphis fabae*. *Physiological Entomology*, **14**: 451-458.

Nugnes, F., Russo, E., Viggiani, G. & U. Bernardo. 2018. First Record of an Invasive Fruit Fly Belonging to *Bactrocera dorsalis* complex (Diptera: Tephritidae) in Europe. *Insects*, **9** (4): 182. https://doi.org/10.3390/insects9040182

Odero, J., Gomes, B., Fillinger, U. & Weetman, D. 2018. Detection and quantification of *Anopheles gambiae* sensu lato mosquito larvae in experimental aquatic habitats using environmental DNA (eDNA). *Wellcome Open Research,* **3**: 26. https://doi.org/10.12688/wellcomeopenres.14193.1

OEPP/EPPO. 1991. EPPO Standards PM 3/30 Phytosanitary procedures for *Globodera pallida & G. rostochiensis*. Soil sampling methods. Bulletin OEPP/EPPO Bulletin **21**, 233–240.

O'Dowd, D. 2009. Anoplolepis gracilipes factsheet. Centre for Analysis and Management of Biological Invasions, Australia & IUCN/SSC Invasive Species Specialist Group (ISSG). www. issg.org/database/species Accessed May 2019.

O'Dowd, D.J., P.T. Green & Lake, P.S. 1999. Status, impact, and recommendations for research and management of exotic invasive ants in Christmas Island National Park. Environment Australia, Darwin. Available online http://www.piat.org.nz/uploads/PIAT_content/pdfs/ODowd%20et%20al_1999.pdf Accessed May 2019

Ogawa, J. 2011. Key pupal characters for *Aedes albopictus* identification in CA. http://www.mvcac.org/amg/wp-content/uploads/Albopictus-pupae-quick-ID-sheet.pdf. Accessed 7th March 2019.

O'Malley, C.M. 1992. The biology of *Anopheles quadrimaculatus* Say. Proceedings of the New Jersey Mosquito Control Association **79**: 136-144.

Pacit, J. 1967. On South and Central African Collembola*.* Journal of the Entomological Society*. of* South Africa **29***:* 135–47.

Pal, M. & Singh, R. 2013. Biology and ecology of the cabbage aphid, *Brevicoryne brassicae* (Linn.) (Homoptera: Aphididae): a review. *Journal of Aphidology* **27**, 59-78.

Parola, P. & Didier, R. 2001. Ticks and tick-borne bacterial diseases in humans: an emerging infectious threat. *Clinical Infectious Diseases*, **21**: 897-928.

Pascoe, A. 2001. Turning up the heat on fire ants. *Biosecurity*, **32**: 6.

Pavon-Gozalo, P., Mila, B., Alexiandre, P., Calderon, J., Zaldivar-Riveron, A., Hernandez-Montoya, M., Garcia-Paris, M. 2011. Invasion of two widely separated areas of Mexico by *Forficula auricularia* (Dermaptera: Forficuladae). *Florida Entomologist,* **94**(4): 1088-1090.

Phillips, M.S., Hackett, C.A., Trudgill, D.L. 1991. The relationship between the initial and final population densities of the potato cyst nematode *Globodera pallida* for partially resistant potatoes. Journal of Applied Ecology, **28**(1):109-119.

Porter, S. D. & Tschinkel, W. R. 1993. Fire ant thermal preferences: behavioural control of growth and metabolism. *Behavioural Ecology and Sociobiology*, **32**: 321–329.

Porter, S. D., Williams, D. F., Patterson, R. S. & Fowler, H. G. 1997. Inter-continental differences in the abundance of *Solenopsis* fire ants (Hymenoptera: Formicidae): an escape from natural enemies? *Environmental Entomology*, **26**: 373–384.

Poutsma, J., Loomans, A.J.M., Aukema, B. & Heijerman, T. 2008. Predicting the potential geographic distribution of the harlequin ladybird, *Harmonia axyridis*, using the CLIMEX model. *BioControl*, **53**:103-125.

Prado, C.C., Triana, H.D., Castillo, C.C., & Tulande-M., E. 2018. First records of *Lithobius* (*Lithobius*) *forficatus*(Linnaeus, 1758) and *Lithobius*(*Lithobius*) *obscurus* Meinert, 1872 (Lithobiomorpha, Lithobiidae) introduced to Colombia. *Check List* **14** (3): 559–568 https://doi.org/10.15560/14.3.559

Pryce, D. & Key, R. 2018. St Helena terrestrial invertebrate species list. Version 7.0 04.04.2018. St Helena National Trust.

Pugh, P.J.A. & Convey, P. 2000. Scotia Arc Acari: antiquity and origin. *Zoological Journal of the Linnean Society*, **130**: 309-328.

Qazi, F., Shayanmehr, M. 2014. Additional records for Iranian Collembola (Hexapoda: Entognatha) fauna from Tehran province. Natura Somogyiensis, **25**: 27-34.

Ramirez-Garcia, L., Bravo Mojica H. & Llanderal Cazares C. 1987. Development of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) under different conditions of temperature and humidity. *Agrociencia*, **67**: 161-171.

Randolph, S.E. 2001. The shifting landscapes of tick-borne zoonoses: tick-borne encephalitis and Lyme borreliosis in Europe. *Philosophical Transactions of the Royal Society of London*, **456**: 1045-1056.

Rios, L., Connelly, C. 2015. Common malaria mosquito *Anopheles quadrimaculatus* Say (Insecta: Diptera: Cullicidae) EENY 491. IFAS, University of Florida.

Ring, D. R, Henderson, G. & McCown, C. R. 2002. Evaluation of the Louisiana State program to treat trees infested with Formosan subterranean termites (Isoptera: Rhinotermidae). In: Jones, SC, Zhai, J & Robinson, WH, eds. *Proceedings of the 4th International Conference on Urban Pests, Charleston, South Carolina*. 259-266.

Rizzoli, A., Rosa, R., Mantelli, B., Pecchoili, E., Hauffe, H., Taqliapietra, V., Benineti, T., Neteler, M., Genchi, C. 2004. *Ixodes ricinus*, transmitted diseases and reservoirs. *Parasitologia*, **46** (1-2):119-122.

Roberts, P., Stone, A.R. 1981. Host ranges of Globodera species within Solanum subgenus Leptostemonum. Nematologica, **27**(2):172-189.

Roberts, L. & Janovy J. Jr. 2000. *Foundations of Parasitology sixth edition*. United States: McGraw-Hill Companies.

Robertson L.C., Prior, S., Apperson, C.S., Irby, W.S. 1993. Bionomics of *Anopheles quadrimaculatus* and *Culex erraticus* (Diptera: Culicidae) in the Falls Lake Basin, North Carolina: seasonal changes in abundance and gonotrophic status and host feeding patterns. Journal of Medical Entomology, **30**: 689-698.

Romanski, A. 2001. Introduced Species Summary Project: Little Fire Ant (*Wasmannia auropunctata*). http://www.columbia.edu/itc/cerc/danoffburg/invasion_bio/inv_spp_summ/Wasmannia_auropunctata.htm#Establishment

Rounsevell, D.E. 1977. Ecology of the pan-Antarctic mite *Nanorchestes antarcticus* (Strandmann). Adaptations within Antarctic ecosystems. *Proceedings of the third SCAR Symposium on Antarctic Biology, Washington, D.C., August 26-30, 1974*, edited by G.A. Llano Pp:1023-1033.

Rounsevell, D.E. 1981. A population of *Nanorchestes antarcticus* (Acari: Prostigmata) at the Vestfold Hills, Antarctica. Australian National Antarctic Research Expeditions (ANARE) Science Report Publications. 131 Antarct. Div. Sci. Hobart 100pp.

Rounsevell, D.E., & Greenslade, P. 1988. Cuticle structure and habitat in the Nanorchestidae (Acari: Prostigmata). Hydrobiologia, **165**: 209-219.

Roy, H.E. & Brown, P.M.J. 2015. Ten years of invasion: *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in Great Britain. *Ecological Entomology* **40**(4): 336-348.

Roy, H., Brown, P. & Majerus, M. 2006. *Harmonia axyridis*: A successful biocontrol agent or an invasive threat? *In: An Ecological and Societal Approach to Biological Control*: 295-309.

Saifur, R.G., Dieng, H., Hassan, A.A., Salmah, M.R., Satho, T, Miake, F., et al. Changing domesticity of *Aedes aegypti* in northern peninsular Malaysia: reproductive consequences and potential epidemiological implications. *PloS one*.7(2): e30919. https://doi.org/10.1371/journal.pone.0030919

Sánchez, E., Castillo, D. & Liria, J. 2017. Pupal shape and size dimorphism in *Aedes albopictus*. *Journal of Threatened Taxa*, **9**(6): 10314-10319.

Sarnat, E.M. 2008. PIAkey: Identification guide to ants of the Pacific Islands, Edition 2.0, Lucid v. 3.4. USDA/APHIS/PPQ Center for Plant Health Science and Technology and University of California – Davis. http://idtools.org/id/ants/pia/index.html. Accessed February 2019.

Scott, J.A., Brogdon, W.G., & Collins, F. H. 1993. Identification of Single Specimens of The *Anopheles gambiae* complex by the Polymerase Chain-Reaction. *The American journal of tropical medicine and hygiene.* **49**. 520-9. 10.4269/ajtmh.1993.49.520.

Seewooruthun, S. I., Permalloo, S., Sookar, P. & Soonnoo, A. R. 2000. The oriental fruit fly, *Bactrocera dorsalis* eradicated from Mauritius. In: Price NS, Seewooruthun I, eds. Proceedings of the Indian Ocean Commission, Regional Fruit Fly Symposium, Flic en Flac, Mauritius, 5th-9th June, 2000 Quatre Bornes, Mauritius: Indian Ocean Commission, 207-210.

Seymour, P. R., Roberts, H. & Davis, M.E (Compilers). 1985. Insects and other invertebrates found in plant material imported into England and Wales, 1984. Reference Book, Ministry of Agriculture, Fisheries and Food, UK, 442/84.

Shannag, H.K. & Ababneh, J.A. 2007. Influence of black bean aphid, *Aphid fabae* Scopoli on growth rates of faba bean. *World Journal of Agricultural Sciences*, **3**: 344-349.

Sharma, S., Warner, J. & Scheffrahn, R.H. 2017 Tawny crazy ant (previously known as Caribbean crazy ant) Nylanderia (formerly Paratrechina) fulva (Mayr)(Insecta: Hymenoptera: Formicidae: Forminicinae). UF/IFAS Extension, Gainesville, EENY610

Siqueira HÂA, Guedes RNC, Picanço MC, 2000. Insecticide resistance in populations of *Tuta absoluta* (Lepidoptera: Gelechiidae). *Agricultural and Forest Entomology*, **2**(2):147-153.

Smith, M.R. 1965. Household infesting ant of the eastern United States: their recognition, biology, and economic importance. Washington, U.S. Department of Agriculture Technical Bulletin No. 1326. 105p.

Smith, I.M., McNamara, D. G., Scott, P. R. & Holderness, M. 1997. *Spodoptera frugiperda*. In: Quarantine Pests for Europe, 2nd Edn., CABI/EPPO, Wallingford, 1425pp.

Sonenshine, D.E., 1991. Biology of Ticks, Part 1. Oxford University Press, New York.

Stals, R. & Prinsloo, G. 2007. Discovery of an alien invasive, predatory insect in South Africa: the multicoloured Asian ladybird beetle, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). *South African Journal of Science*, **103** (3/4): 123-126.

Stenn, T., Peck, K.J., Rocha Pereira, G. & N. D. Burkett-Cadena. 2019. Vertebrate Hosts of *Aedes aegypti*, *Aedes albopictus*, and *Culex quinquefasciatus* (Diptera: Culicidae) as Potential Vectors of Zika Virus. Florida *Journal of Medical Entomology*, **56**:1, pgs 10–17.

Stewart, J. S. & Vinson, S. B. 1991. Red imported fire ant damage to commercial cucumber and sunflower plants. *Southwestern Entomologist*, **16**: 168-170.

Stone, A.R. 1973a. CIH Descriptions of plant parasitic nematodes No. 16. *Globodera rostochiensis*. CAB International, Wallingford (GB).

Stone, A.R. 1973b. CIH Descriptions of plant parasitic nematodes No. 15. *Globodera pallida*. CAB International, Wallingford (GB).

Stringer, L. D., Suckling, M. D., Baird, D., Vander Meer, R. K., Christian, S. J. & Lester, P. J. 2011. Sampling efficacy for the Red Imported Fire Ant *Solenopsis invicta* (Hymenoptera: Formicidae). *Environmental Entomology*, **40**(5): 1276-1284.

Suarez, A.V., Holway, D.A. & Case, T.J. (2001) Patterns of spread in biological invasions dominated by long-distance jump dispersal: Insights from Argentine ants. *PNAS*, **98** (3): 1095-1100.

Sullivan, M.J., Inserra, R.N., Franco, J., Moreno-Leheudé, I., Greco, N. 2007. Potato cyst nematodes: plant host status and their regulatory impact. Nematropica, **37**(2):193-201. http://palmm.fcla.edu/nematode/

Suman DS, Shrvastava AR, Pant SC, Parashar BD (2011) Differentiation of *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) with egg surface morphology and morphometrics using scanning electron microscopy. *Arthropod Structure and Development* **40**: 479-484.

Suszkiw, J. 1998. The Formosan termite: A formidable foe. *Agricultural Research*, **46**: 4-9.

Suszkiw, J. 2000. Taking aim at Formosal subterranean termites. *Agricultural Research*, **48**: 12-15.

Swanson, S.J., Neitzel, D., Reed, K.D. & Belongia, E.A. 2006. Coinfections acquired from *Ixodes* ticks. *Clinical Microbiology Reviews*, **19** (4): 708-727.

Taber, S. W. 2000. Fire Ants. College Station, Texas: Texas A&M University Press, 308 pp.

Tsutsui, N.D.; Case, T.J. 2001. Population genetics and colony structure of the Argentine ant (*Linepithema humile*) in its native and introduced ranges. *Evolution* **55**: 976-985.

University of California Agriculture and Natural Resources. 2008. UC Management Guidelines for Black Bean Aphid on Celery. http://ipm.ucanr.edu/PMG/r104300211.html . Accessed 1st May 2019.

Van der Groot, P. 1916. Verdere onderzoekingen omtrent de oeconoommische beteekenis der gramang-mier. Mededeelingen van het Proefstation Midden-Java, *Salatiga* **22**: 1-122 summarized in English in *Rev. Appl. Entomol* **5**: 273-276.

Van Riel, H.R. & Mulder, A. 1998. Potato cyst nematodes (Globodera species) in western Europe. In: Potato Cyst Nematodes: Biology, Distribution and Control (Ed. Marks RJ & Brodie BB), pp. 271–298. CAB International, Wallingford (GB).

Vanderwoude, C., Lobry de Bruyn, L.A. & House, A.P.N. 2000. Response of an open-forest ant community to invasion by the introduced ant, *Pheidole megacephala*. *Austral Ecology*, **25**:253-259.

Vargas, R. I., Piñero, J. C. & Leblanc L. 2015. An overview of pest species of *Bactrocera* fruit flies (Diptera: Tephritidae) and the integration of biopesticides with other biological approaches for their management with a focus on the Pacific region. *Insects*, **6**(2): 297-318. http://www.mdpi.com/2075-4450/6/2/297/htm/

Vayssières, J. F., Korie, S., & Ayegnon, D. 2009. Correlation of fruit fly (Diptera Tephritidae) infestation of major mango cultivars in Borgou (Benin) with abiotic and biotic factors and assessment of damage. *Crop Protection*, 28, 477– 488.

Vayssières, J.F., De Meyer, M., Ouagoussounon, I., Sinzogan, A., Adandonon, A., Korie, S., Wargui, R., Anato, F., Houngbo, H., Didier, D., De Bon, H. & Goergen, G. 2015. Seasonal abundance of mango fruit flies (Diptera: Tephritidae) and ecological implications for their management in mango and cashew.*J. Econ. Entomol.***108**(5):2213-30

Vinson, S. B. 1997. Invasion of the red imported fire ant: spread, biology and impact. *American Entomologist*, **43**: 23-39.

Virgilio, M., White, I. & De Meyer, M. 2014. Factsheet *Ceratitis cosyra* in: A set of multi-entry identification keys to African frugivorous flies (Diptera, Tephritidae). ZooKeys 428: 97-108. doi:10.3897/zookeys.428.7366

Virgilio, M., White, I. & De Meyer, M. 2014. Factsheet *Dacus bivittatus* (Bigot) in: A set of multi-entry identification keys to African frugivorous flies (Diptera, Tephritidae). *ZooKeys* **428**: 97-108. doi:10.3897/zookeys.428.7366

Virgilio, M., Manrakhan, A., Delatte., H., Daneel, J.H., Mwatawala, M., Meganck, K., Barr, N., & De Meyer, M. 2017. The complex case of *Ceratitis cosyra* (Diptera, Tephritidae) and relatives. A DNA barcoding perspective. *Journal of Applied Entomology* https://doi.org/10.1111/jen.12379

Vonshak, M., Dayan, T., Ionescu-Hirsh, A., Freidberg, A., Hefetz A. 2009 The little fire ant *Wasmannia auropunctata*: a new invasive species in the Middle East and its impact on the local arthropod fauna. *Biological Invasions*, **10** (6):1825-1837.

Walker, K.A.; Jones, T.H.; Fell, R.D. 1993. Pheremonal basis of aggregation in European earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae). *Journal of Chemical Ecology*, **19**: 2029-2038.

Walsh, J., Carpenter, S., & Vander Zanden, J. 2016. Invasive species triggers a massive loss of ecosystem services through a trophic cascade. *Proceedings of the National Academy of Sciences*. **113**. 201600366. 10.1073/pnas.1600366113.

Wang, L.Y. 1986. Mass rearing and utilization in biological control of the lady beetle *Leis axyridis* (Palla) [*Harmonia axyridis*]. *Acta Entomologica Sinica*, **29**(1):104.

Wang, Z., Moshman, L., Kraus, E.C., Wilson, B.E., Acharya, N. & Diaz, R. 2016. A review of the Tawny Crazy Ant, *Nylanderia fulva*, an emergent ant invader in the southern United States: Is Biological Control a feasible management option? *Insect*, **7**(4):77.

WaspWeb, 2019. Wasp Web: Information on *Vespula* Wasps in New Zealand: First Aid. Landcare Research. www.landcareresearch.co.nz/science/plants-animals-fungi/animals/invertebrates/invasive-invertebrates/wasps/first-aid Accessed March 2019.

Weathersbee, A.A. and Meisch, M.V. 1990. Dispersal of *Anopheles quadrimaculatus* (Diptera; Culicidae) in Arkansas Riceland. Environmental Entomology, **19** (4): 961-965.

Weidhass, D.E., Woodare, D.B., Schmidt, C.H., Ford, H.R. 1965. Biology of *Anopheles quadrimaculatus* under field conditions in central Florida. Annals of the Entomological Society of America, **58**: 145-150.

Wetterer, J. 2005. Worldwide distribution and potential spread of the long-legged ant, *Anoplolepis gracilipes* (Hymenoptera: Formicidae). *Sociobiology.* **45**: 77-97.

Wetterer, J.K. 2007. Biology and impacts of Pacific island invasive species. 3. The African bigheaded ant, *Pheidole megacephala* (Hymenoptera: Formicidae). *Pacific Science*, **61** (4): 437-456.

Wetterer, J.K. 2009. Worldwide spread of the destroyer ant, Monomorium destructor (Hymenoptera: Formicidae) *Myrmecological News* **12**: 97-108.

Wetterer, J. K. 2013. Exotic spread of Solenopsis invicta (Hymenoptera: Formicidae) beyond North America. *Sociobiology,* **60**: 50–55.

Wetterer, J. K. & Snelling, R. R. 2006. The red imported fire ant, *Solenopsis invicta*, in the Virgin Islands (Hymenoptera: Formicidae). *The Florida Entomologist,* ***89***(4): *431–434.* http://www.bioone.org/doi/abs/10.1653/0015-4040%282006%2989%5B431%3ATRIFAS%5D2.0.CO%3B2.

Wetterer, J.K. & Porter, S.D. 2003. The little fire ant, *Wasmannia auropunctata*: distribution, impact, and control. *Sociobiology*, **42**:1–41.

Wetterer, J.K., Wetterer, A.L. & Hebard, E. 2001. Impact of the Argentine Ant, *Linepithema humile*, on the Native Ants of Santa Cruz Island, California. *Sociobiology*, **38** (3B): 1-13.

WHO. 2004. World Health Organization. (On-line). Accessed 12/15/04 at http://www.who.int/tdr/research/progress/mal_str/default.htm.

Zaheer, K., Fleming, C., Turner, S.J., Kerr, J.A.; McAdam, J. 1992. Genetic variation and pathotype response in *Globodera pallida* (Nematoda: Heteroderidae) from the Falkland Islands. Nematologica, **38**(2):175-189; 27.

Zettel. C & Kaufman, P. 2008 (reviewed 2018). Yellow fever mosquito: *Aedes aegypti* (Linnaeus) (Insecta: Diptera: Culicidae) Gainesville, Florida, USA: University of Florida, IFAS extension [EENY-434]

9. Appendices

9.1 Major sources of further information

The following list of websites provide a wealth of freely accessible information on invasive alien species that pose a potential pant health risk to the UKOTs in the Atlantic. They also provide links to further sources of information:

CABI. 2007. Crop Protection Compendium. http://www.cabicompendium.org/.

CABI. 2019. Invasive species Compendium. http://www.cabi.org/isc.

CABI. 2019. Plantwise. https://www.plantwise.org/

EPPO. 2019. European and Mediterranean Plant Protection Organization (EPPO)

https://www.eppo.int/

NNSS. 2019. GB Non-Native Species Secretariat – UK Overseas Territories Home – http://www.nonnativespecies.org/ots/otsMap.cfm

ISSG. 2014. Global Invasive Species Database. http://www.iucngisd.org/gisd/

9.2 Fera invertebrate plant pest identification Services for the UKOTs

Defra provide to Fera to provide an identification service for suspected invasive alien invertebrate plant pests found in the UKOTs. A submission form and instructions on how to submit a sample are given below.

UK Overseas Territories Sample Submission Form

fera

To help us with our diagnosis, please try and fill in as much information as possible?

For Fera use only:

Your Details

Name:		Date:		
Department/Organisation:		Your Ref:		
Address:		Tel:		☐*
		Fax:		☐*
		Email:		☐*

* Tick preferred method of contact

The Sample

Type of sample:	Plant/Produce Import Interception ☐ Locally grown plant(s) ☐ Other (give details) ☐		
Type of pest:	Insect ☐ Mite ☐ Nematode ☐ Other (give details) ☐ Unknown ☐		
What do you suspect the pest to be?			
Approximate numbers of organisms found:		Life-stage(s) (if known):	
Sample preservation: (see over for recommended methods)	Live ☐ Dried/pinned ☐ Slide mounted ☐ Fluid preserved (please give details) ☐		

The Host

Plant genus, species:	
Description of host damage (if any):	
Country of origin:	
Other information:	

I hereby authorise Fera to carry out diagnostic work on this sample.	Signature:	

Sending your sample for diagnosis

How to collect, package and send your sample

How a sample is preserved before posting is largely dependent on how long it will take to reach us. Please contact us for advice if you are unsure of how to collect and package a particular sample or if you wish to send photos of pests and/or pest damage before submitting a sample. Please email: ukot@fera.co.uk

Collecting and Packaging:

- Provide as many individual specimens of each suspected species as possible. Some species are highly variable, or there may be mixed populations of related species on a host.
- In some cases, adult life stages are necessary for species determination. Larval forms of most Diptera (flies) and Lepidoptera (butterflies and moths) should ideally be collected with their food source and reared on before sending.

Beetles, adult Lepidoptera, and other robust bodied invertebrates	Kill before sending, freezing is preferable. Carefully place the dead insect in a small tube or box and lightly wrap it with tissue (enough to stop it rattling around and becoming damaged). Avoid airtight containers due to possible mould formation. Prevent this by puncturing a few holes in the tube or box. Moths and butterflies can also placed in paper or glassine envelopes, but take care not to crush them. Pinning, carding and setting of organisms before posting is welcomed, please contact us if you require instructions.
Larval invertebrates	Place in a small plastic tube filled with ethanol (70%).
Scale insects, aphids, whitefly pupae and mites	Leave on the host where possible. Removing them can damage them making identification more difficult. Place the host leaf or stem in a plastic pot of 70% ethanol. With larger leaves or stems, or if the sample is going to take a while to reach us it is necessary to change the preservative after 4-5 days as the plant material will dilute the ethanol and the invertebrates will begin to rot. If you have to detach specimens from the host material this is best done with a fine paintbrush or fine forceps. Place them in a small plastic container filled with ethanol (70%). Do not send specimens in formalin or any other formaldehyde based preservative.
Soil samples	For nematode analysis. Place about 500g of soil in a strong plastic bag and seal.
Sticky traps	Label, bend round sticky side inwards, and secure in position with adhesive tape.

Labelling and Posting:

- Each sample must be clearly labelled indicating host association, date collected, locality, reference numbers and any other pertinent information. Pictures of associated host damage are also useful.
- All samples should be put in a strong cardboard box and packaged securely. Include your Sample Submission Form licence and permits seal the box. We will provide you with a copy of our licence 'Letter of Authority'.
- On the outside of the parcel a label should state "Dead Invertebrates for Scientific Study - No Commercial Value". Please also place a copy of the appropriate permits and licences in and envelope and secure to the outside of the parcel.
- If the parcel is being sent by courier, please send us the tracking reference if possible.

Send your sample to: UKOT Project (Room 02FA04)
Fera Science Ltd
Sand Hutton
York
YO41 1LZ
United Kingdom

If you have any queries, contact: Sharon Reid or Dr. Chris Malumphy
Tel: +44 (0)1904 462000
E-mail: ukot@fera.co.uK