Services and dis-services of rainforest insects to crops in north Queensland

What we know
What we need to know
Why it is important

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PREFACE

North Queensland tropical rainforest has the reputation of harbouring arthropods that are crop pests - but it is also likely to be the source of beneficial arthropods. At present this positive contribution to crops is largely unrecognised and untapped. This report, an assessment of common perceptions and documented research, is the first step toward providing a clearer picture of the relative importance of the services (pollination and biocontrol) and dis-services (pests) to agriculture from tropical rainforest insects.

Pollinators

Flower wasp
Campsomeris tasmaniensis
Saussure, P. Branwhite

Hawk Moth *Macroglossum* spp.
D. Herbison-Evans, S. Crossley
and the Queensland Museum

Pests

Avocado fruit borer *Thaumatotibia zophophanes* (Turner), R. Bauer

Avocado leaf roller *Homona spargotis* Meyrick, DPI, Queensland

Protectors

Parasitoid Wasp
Euplectrus sp. Saninet

Predatory green lacewing
Italochrysa insignisnes
(Walker), CSIRO Entomology

ACKNOWLEDGEMENTS

We would like to thank the growers, land managers and scientists who generously gave their time and expertise to help us understand the environmental diversity of the Atherton Tablelands and nearby coastal areas, and the perceived role of rainforest insects in crops in the region.

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INTRODUCTION

In addition to aesthetic appeal, and the economic value of the timber they contain, native forests contribute less obvious services to society by regulating water flow, storing carbon, supplying new pharmaceutical chemicals and acting as refuges for fauna. Alternatively, forests can have negative impacts on human activities by harbouring pests.

We are undertaking a study to examine the role of rainforest insects both in terms of the benefits, and the problems, they present to crops in the Atherton region of north Queensland. We are comparing pollination, herbivory and biological control of pest arthropods in production systems adjacent to rainforest, with those far from rainforest. The economic significance of these services and dis-services will be evaluated by estimating the cost of providing the services in other ways and the extent of losses caused by pests. Ultimately this research will allow the contributions of rainforest insects to be better incorporated into decision-making on crop management and natural resource use.

An initial survey of existing information about production systems and the insects found in them has now been completed. This was based on published information and consultation with growers, land managers and researchers. A series of field-based case studies arising from the survey has commenced.

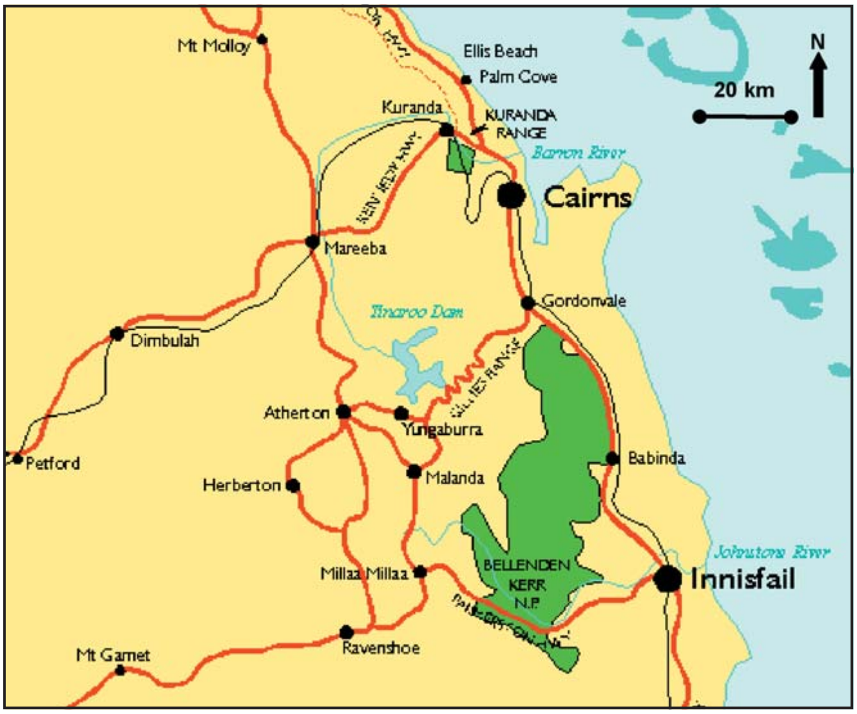
The results of the initial survey are summarised in this report. The first section outlines the main characteristics of the region and emphasises the diversity of the environment and the changes in vegetation and agriculture since European settlement. The second section explains why it is important to find insects other than honey bees to pollinate crops and why rainforests are likely sources of such insects. Then it demonstrates that while only a small proportion of crop pests have connections with rainforest, these pests are among the most difficult to manage. It highlights the need for research on rainforest parasitoids and predators capable of helping control pests and reducing pesticide use. The final section summarises the survey findings and their significance.

THE REGION

THE ENVIRONMENT

The area of interest for this project comprises the region from Dimbulah in the west, Mareeba in the north and Ravenshoe in the south, plus adjoining coastal areas from the South Johnstone River to Cairns (Fig. 1).

Fig. 1. Study area



The environment of this region is diverse in every way. Elevation, rainfall and temperature vary markedly over short distances (Table 1). Soils range, for example, from the red, high clay, fertile soils at Atherton, derived from basalt, to the sandy, less fertile loams derived from granite at Mareeba (Campbell 1998).

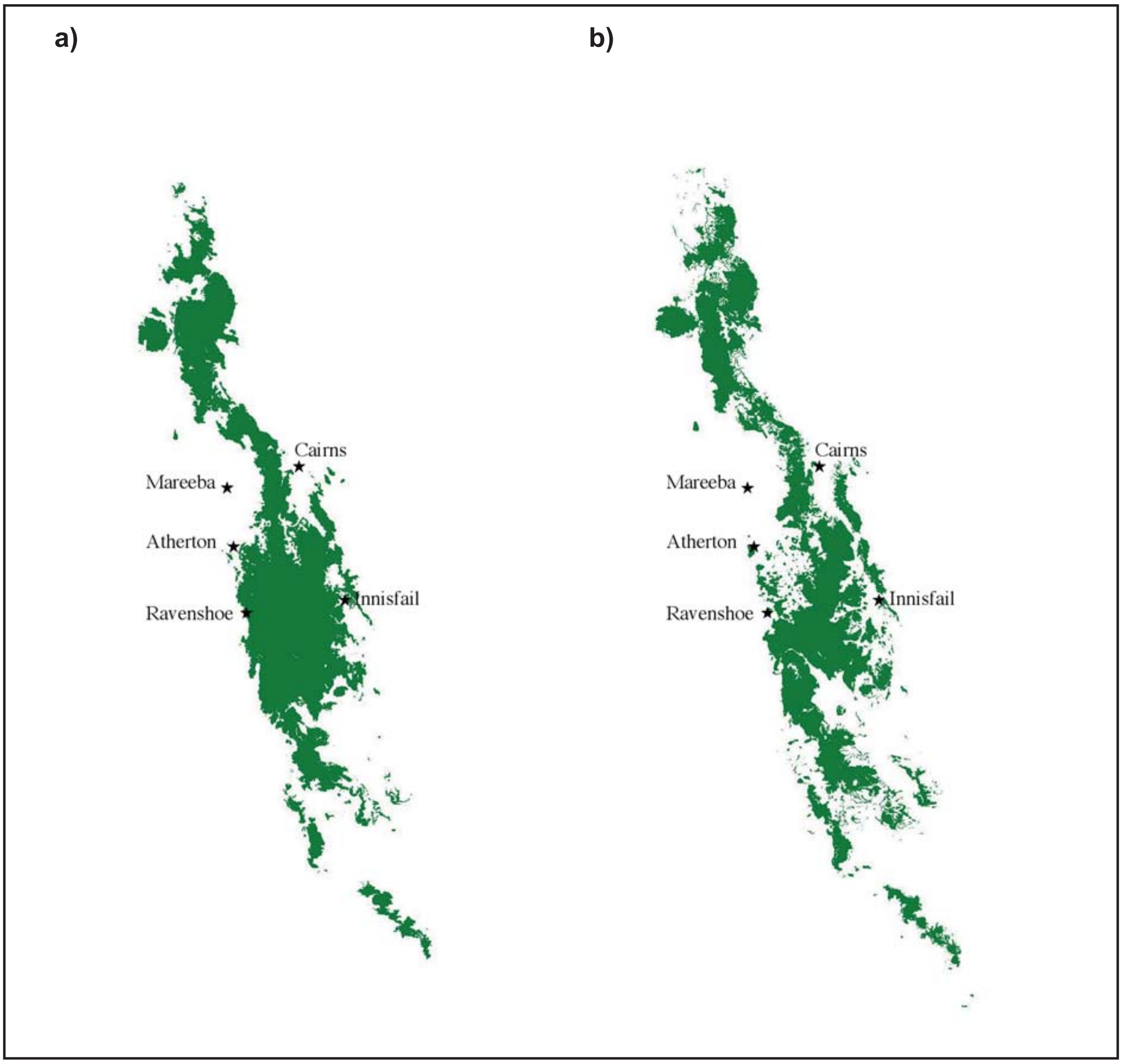
Table 1. Environmental attributes of the Atherton Tablelands and adjacent coastal areas (Clewett *et al*. 1999; Department of Primary Industries Queensland 2000a; Bureau of Meteorology 2001).

LOCATION	LAT.	LONGIT.	ELEVATION (m)	MEDIAN ANNUAL RAINFALL (mm)	TEMPERATURE RANGE (max-min °C)
Cairns	16.9333 S	145.7899 E	2	2045	29 - 21
Mareeba	16.9950 S	145.4253 E	406	880	32 - 11
Dimbulah	17.1492 S	145.1086 E	407	721	35 - 10
Atherton	17.2667 S	145.4833 E	770	1308	30 - 10
Malanda	17.3333 S	145.5833 E	762	1565	28 - 8
South Johnstone	17.6056 S	145.9972 E	18	3297	28 - 19
Ravenshoe	17.6666 S	145.2833 E	920	842	not available

THE RAINFOREST

When white settlers arrived in the Atherton Tablelands region, in the mid 1800s, rainforest was a major vegetation type (Walker 1979). Tree-clearing began with miners and timber-getters and was continued by agriculturalists and pastoralists. It is estimated that 76,412 ha of rainforest have been cleared (Winter *et al.* 1987). Today, apart from the World Heritage Area, only small remnants of rainforest remain on the Atherton Tablelands (Fig. 2). These remnants have been mapped and details of their size, plant species composition, vegetation structure, soil type and topography recorded (Graham *et al*. 1995a, b).

Fig. 2. Extent of tropical rainforest in north Queensland:
a) at the time of white settlement and
b) today
(including present day locations of some towns in the study region)
(Spatial models courtesy Trevor Parker, CSIRO Sustainable Ecosystems, Atherton)



THE CROPS

The earliest crops in the region were Chinese market gardens providing food for mining communities (Eacham Historical Society 1982). These were followed later by sugarcane (on coastal lowlands from the 1890s), bananas, peanuts, potatoes, tobacco, maize and pasture for cattle (Campbell 1998). Today many additional crops have become established, reflecting the environmental diversity of the region (Table 2).

In coastal areas the main crops are still sugarcane and bananas. On the Tablelands sugarcane is expanding (Department of Primary Industries Queensland 1999a) and mangos and avocados, both relatively new crops, now also have high economic value (Table 2). Some crops, like tobacco and navy beans, are currently declining in importance but many others, including macadamias, longans, lychees, custard apple, cut flowers and rare fruits, are rapidly increasing in suitable parts of the region (Department of Primary Industries Queensland 1999b).

Table 2. Relative importance of Atherton Tableland crops (from Campbell 1998; Chudleigh 1999; Department of Primary Industries Queensland 2000a).

CROP	VALUE ($)	VOLUME (t)	AREA (ha)
sugarcane	33m	1,119,000	9,664
mango	30m	19,000	3,213
avocado	20m	14,400	1,300
tobacco	17.4m	3,000	1,130
potato	9.5m	25,000	1,056
peanut	8.9m	13,095	3,200
banana	~6.3m	not available	~180
macadamia	5.1m	16,670	667
maize	4.5m	32,000	6,800
papaya	4.2m	2,690	63
flowers	3m	-	33
sweet potato	3m	3,500	160
tea tree	3m	100	500
lychee	2.5m	400	215
navy bean	2.4m	3,000	1,200
citrus	2m	1,725	230
pumpkin	1.9m	6,400	320
aquaculture	1.5m	not available	not available
coffee	1.5m	200	100
farm forestry timber	1.25m	not available	not available
longan	1.2m	600	138
custard apple	1.05m	300	30
grape	1m	188	40
passionfruit	0.75m	5	3
cashew	0.16m	100	240
tomato	0.12m	not available	20
stonefruit	0.05m	15	5
onion	0.04m	600	20
rare fruits	not available	not available	not available
tea	not available	not available	600

THE INSECTS

POLLINATORS

In Australia commercial honey bees, *Apis mellifera* Linnaeus, are traditionally recognised as the main crop pollinators. The beekeeping industry in Queensland values pollination activities conservatively at $500,000/year (Gibbs & Muirhead 1998). However, Australian native bees, wasps, beetles, flies and thrips may be just as useful, or even better, pollinators for some plant species. For example, the lycid beetle, *Metriorrhynchus rhipidius* (Macleay), the flower wasp, *Campsomeris tasmaniensis* Saussure, and the halcid bee, *Homalictus* sp. all make important contributions to the pollination of macadamia (Vithanage & Ironside 1986). Stingless bees, especially *Melipona* and *Trigona* spp. are known to be effective pollinators of a least nine crops and contribute to the pollination of about 60 other crop species (Heard 1999).

The need to understand the effectiveness of native pollinators and develop ways to encourage and sustain their services, is highlighted by widespread declines in bee faunas detected in central Europe and suspected elsewhere (Cane & Tepedino 2001). These declines are thought to be caused by factors such as habitat loss, pesticide use, parasitism and disease (Black *et al*. 2001; Kevan & Phillips 2001). The parasitic mite, *Varroa destructor* Anderson & Trueman, regarded as the most serious pest of commercial honey bees, was confirmed present in New Zealand in 2000 (CSIRO media release, 24th May 2000). This leaves Australia in the precarious position of being the only remaining major bee-keeping country where this pest does not occur. It is probable, given the ease with which *V. destructor* has spread in the past, that it will eventually invade Australia. This threat, coupled with high pesticide use and the recent outbreak of American Foul Brood disease in honey bees at Ravenshoe, suggests that declines in honey bee numbers are likely in the Atherton Tableland region (Department of Primary Industries Queensland 2001).

Pollination services provided to crops by insects from Australian tropical rainforests have rarely been documented. Pollination of papaya by hawk moths, *Macroglossum* spp., which also pollinate the rainforest tree, *Syzygium tierneyanum* (F. Muell.), (Hopper 1980), and whose larvae feed on several rainforest plant species, is perhaps the best known example (Morrisen 1995).

It has been predicted that many dry rainforest canopy trees are likely to be pollinated by small generalist insect species (Hansman 2001). Crops with flowers similar to dry rainforest trees may also be pollinated by these generalist insect species. A species like the flower scarab, *Phyllotocus apicalis* Macleay, that pollinates the rainforest tree, *Flindersia brayleyana* F. Muell., is a potential crop pollinator because it is also attracted to many non-rainforest plants (Irvine & Armstrong 1988). Given the high diversity of flower-visiting insect species observed in a study of just three of the hundreds of plant species in tropical rainforest on the Atherton Tablelands (House 1989) it seems likely that many useful crop pollinators await discovery.

Of crops listed in Table 2 as worth more than $1m/year in the Atherton region macadamia (Heard 1993; Heard 1994; Heard & Exley 1994), custard apple (George *et al.* 1989), papaya (Morrisen 1995), lychee and longan (McConchie & Batten 1989), peanut (Rashad *et al*. 1979), pumpkin (Department of Agriculture Western Australia 2000), coffee (Department of Agriculture Western Australia 1998) and mango (Anderson *et al*. 1982) are known to either require insect pollinators, or have yields enhanced by insect pollination. The contribution of insects to avocado (Davenport *et al*. 1994) and citrus (Sanford 1992) pollination is controversial. Only the insect pollinators of papaya (Morrison 1995) and macadamia (Heard 1993; Heard 1994) have been researched extensively in Queensland.

Custard apple, or atemoya, is a good example of a crop that could benefit greatly from pollination by native insects. Most growers currently carry out labour-intensive hand pollination for several weeks/ year. Pollination occurs when the flower is in the receptive female stage but this is also when the flower is barely open and only tiny insects can enter. By the time the flower opens further it is in the male phase and usually no longer receptive to pollination. Larger insects that then have access, like honey bees, merely rob the flower of its pollen.

Custard apples are known to be pollinated by four species of nitidulid beetle in Israel (Gazit *et al*. 1982) and seven species in Florida (Nadel & Peña 1994). Only one of these species, *Carpophilus hemipterus* (Linnaeus), has been recorded pollinating custard apple in Australia (George *et al*. 1989) but we have recently observed at least eight species visiting female flowers in orchards near Atherton (Fig. 3).

It is possible that some of these beetles originated from populations in rainforest that pollinate plant species closely related to custard apple. Many of these related plant species, for example, *Cananga odorata* (Lam.) Hook f. & Thomson (ylang ylang) (Fig. 4) have similar kinds of flowers to custard apple .

Fig. 3. Custard apple flower and some of the beetles found in female stage custard apple flowers on the Atherton Tablelands.
All beetles are less than 3mm long. (Photographs R. Bauer)

Fig. 4. *Cananga odorata* (ylang ylang).
An economically important rainforest plant. Its pollinators may also pollinate custard apple. (Extracts from this flower are used in making Chanel #5 perfume.) (Photograph J-B. Prieur)

PESTS

Only 18 of the 49 economically important arthropod pests of the major crops listed in Table 2 are of Australian origin (Table 3). The remainder (63%) are introduced species. Only nine pest species have verified connections with tropical rainforest but it is likely that at least some, especially generalist species like the yellow peach moth and green coffee scale, are able to utilise rainforest plants.

Seven of the nine species known to use rainforest plants for some part of their life cycle are native species (Table 3). The exceptions are the cane weevil borer from New Guinea, that attacks rainforest palms (Agnew 1997) and the widespread pink wax scale, whose hosts include the rainforest umbrella tree, *Schefflera actinophylla* (Endl.) Harms (Smith *et al*. 1997).

Some of the pests associated with rainforest plants, such as fruit flies (Drew *et al*. 1984), pink wax scale (Smith *et al* 1997), the banana-spotting bug (Brimblecombe 1948) (Fig. 5) and fruit-piercing moths (Fay 1996) (Fig. 6) are among the most difficult to control and cause damage to the greatest number of crops. They are responsible for the perception that planting crops near rainforest, or rainforest remnants, is unwise.

It is essential that we understand more about the ecology of native and introduced pest arthropods so that we can develop better management strategies to reduce their impacts on crops.

Fig. 5. Banana-spotting bug.
Rainforest hosts of the banana-spotting bug include the umbrella tree, *Schefflera actinophylla*, and white cedar, *Melia azedarach* L. Adults and nymphs attack numerous commercial fruits. (Photograph courtesy DPI Queensland)

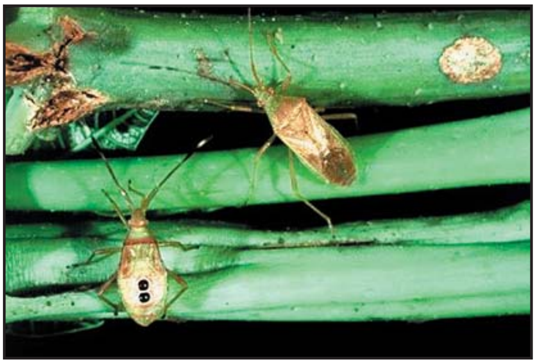


Fig. 6. Fruit-piercing moth.
The larvae of fruit-piercing moths feed on twining rainforest vines of the Menispermaceae, such as snake vine, *Tinospora smilacina* Benth. Adults are capable of damaging most commercially grown fruits. (Photographs P. Hubert)

Table 3. Economically important arthropod pests in the Atherton region, their origin, relationship with rainforest, and the crops they damage.

Compiled from: Sinclair 1979; Waite 1988; Ridgeway 1989; Broadley 1991; Fay & Huwer 1993; Fay *et al.* 1993; Crosthwaite 1994; Pinese & Piper 1994; Robertson & Webster 1995; Robertson *et al*. 1995; Brough *et al*. 1996; Ironside 1995; Agnew 1997; Smith *et al*. 1997; Peña *et al*. 1998; Waite & Huwer 1998; Pinese *et al*. 2001; Sallam & Garrad 2001; Waterhouse & Sands 2001.

COMMON NAME	SPECIES NAME	ORIGIN	FOUND IN RAINFOREST	CROPS AFFECTED BY PEST
avocado fruit borer	*Thaumatotibia zophophanes* (Turner)	Australia	yes	avocado
avocado leaf roller	*Homona spargotis* Meyrick	? Australia	?	avocado, custard apple, tea, coffee, lychee, & etc
banana rust thrips	*Chaetanaphothrips signipennis* (Bagnall)	exotic	?	banana
banana scab moth	*Nacoleia octasema* (Meyrick)	part Asia/ Oceana	?	banana
banana spider mite	*Tetranychus lambi* Pritchard & Baker	? Australia	?	numerous crops
banana weevil borer	*Cosmopolites sordidus* (Germar)	Indo-Malaysia	?	banana
banana-spotting bug	*Amblypelta lutescens lutescens* (Distant)	Australia	yes	most fruits
bean fly	*Ophiomyia phaseoli* (Tryon)	exotic	?	bean
cane weevil borer	*Rhabdoscelus obscurus* (Boisduval)	New Guinea	yes	sugarcane, banana
canegrubs	*Lepidiota* spp.	Australia	yes	peanut, sugarcane, pasture
citrus bud mite	*Eriophyes sheldoni* (Ewing)	exotic	?	citrus
citrus gall wasp	*Bruchophagus fellis* (Girault)	Australia	?	citrus
citrus mealybug	*Planococcus citri* (Risso)	exotic	?	most fruits
citrus rust mite	*Phyllocoptruta oleivora* (Ashmead)	E & SE Asia	?	citrus
citrus snow scale	*Unaspis citri* (Comstock)	SE Asia	no	citrus
common mango scale	*Aulacaspis tubercularis* Newstead	exotic	?	mango
corn earworm	*Helicoverpa armigera* (Hübner)	S Europ. & Medit.	?	corn, bean, tobacco, & etc., & etc.
ectropis looper	*Ectropis sabulosa* ?	? Australia	?	avocado
erinose mite	*Eriophyes litchii* Keifer	?	?	lychee
fruit-piercing moths	*Eudocima* spp.	Aust., SE Asia, Africa	yes	most fruits
green coffee scale	*Coccus viridis* (Green)	tropics	?	citrus, coffee, lychee, longan, mango
hemispherical scale	*Saissetia coffeae* (Walker)	Africa	?	citrus, avocado, coffee
lacebug	*Ulonemia concava* Drake	Australia	?	macadamia
latania scale	*Hemiberlesia lataniae* (Signoret)	exotic	?	avocado, macadamia

macadamia flower caterpillar	*Cryptoblabes hemigypsa* Turner	Australia	yes	macadamia
macadamia nut borers	*Cryptophlebia* spp.	Australia	yes	macadamia, lychee, longan
macadamia weevil	*Sigastus?* sp.	? Australia	?	macadamia
mango planthopper	*Colgaroides acuminata* (Walker)	Australia	?	mango
mango scale	*Phenacaspis dilatata* (Green)	exotic	?	mango
mango seed weevil	*Sternochaetus mangiferae* (Fabricius)	Asia, Pacific, Africa	?	mango
mussel scale	*Lepidosaphes beckii* (Newman)	oriental	?	citrus, avocado
nigra scale	*Parasaissetia nigra* (Nietner)	SE Asia or Africa	?	custard apple, avocado, citrus
oriental scale	*Aonidiella orientalis* (Newstead)	? China	?	papaya, mango
pink wax scale	*Ceroplastes rubens* Maskell	? Africa	yes	citrus, mango, avocado, custard apple, longan
potato moth	*Phthorimaea operculella* (Zeller)	S America	?	potato
Queensland fruit fly	*Bactrocera tryoni* (Froggatt)	Australia	yes	most fruits except strawberry & pineapple
red scale	*Aonidiella aurantii* (Maskell)	? China	?	citrus, passionfruit
redbanded thrips	*Selenothrips rubrocinctus* (Giard)	tropics, subtropics	?	avocado, mango, macadamia, cashew
redshouldered leaf beetle	*Monolepta australis* (Jacoby)	? Australia	?	avocado, macadamia, mango, citrus, cashew, corn
rhinocerus beetle	*Xylotrupes gideon* (Linnaeus)	SE Asia	?	lychee
spherical mealybug	*Nipaecoccus viridis* (Newstead)	?Africa, SE Asia	?	citrus
spined citrus bug	*Biprorulus bibax* Breddin	Australia	?	citrus
sugarcane budmoth	*Opogona glycyphaga* Meyrick	Australia	?	banana, sugarcane
sugarcane soldier fly	*Inopus rubriceps* (Macquart)	Australia	no	sugarcane, pasture
swarming leaf beetles	*Rhyparida* spp.	Australia	no	numerous tree crops
sweet potato weevil	*Cylas formicarius elegantulus* Summers	exotic	?	sweet potato, corn
two-spotted mite	*Tetranychus urticae* Kock	? Europe	?	numerous crops
white fringed weevil	*Naupactus leucoloma* (Boheman)	S America	?	peanut, sugarcane, potato, maize, & etc.
yellow peach moth	*Conogethes punctiferalis* (Guenée)	Asia	?	custard apple, macadamia, corn, papaya, lychee, & etc.

PROTECTORS: PARASITOIDS AND PREDATORS OF PEST ARTHROPODS

Pesticides are ineffective if the pests have become resistant to them, if the pesticides degrade rapidly or are washed away by rain, if the pesticides are sprayed during an unreceptive stage in the life cycle of the pest, or if the pesticide does not reach the pest because it is inside a plant organ or protected by a thick canopy. Advice to growers often encourages adoption of integrated pest management (IPM) to reduce use of pesticides and improve their effectiveness (eg. Pinese & Piper 1994; Smith *et al*. 1997). IPM practices include release of biocontrol insects, and monitoring of pest populations to decide when pesticide spraying will be most efficient against the pest, while having least impact on beneficial insects. To achieve successful IPM it is necessary to understand the ecology of both the pest and the beneficial insects.

Consumers are also becoming increasingly concerned about the possible effects of pesticides on human health and on the environment. There is a growing market for ‘clean, green’ food produced without the use of synthetic pesticides (Department of Primary Industries Queensland 2000b; Cosic 2002).

Most of the major pest arthropods in the Atherton region have native or exotic insect parasitoids and/or predators capable of reducing the size of pest populations to some degree (Table 4). Three native and five exotic pest species (16%) have no recorded insect enemies. The effectiveness of insect parasitoids and predators is influenced by many factors, especially the microclimate in the crop, proximity of alternative hosts and the nature and timing of pesticide use (Waterhouse & Sands 2001). To maximise their effectiveness we need to learn where insect enemies of crop pests come from so that we can provide conditions that attract and maintain them in crop situations.

Many of the native predators and parasitoids listed in Table 4 have not been studied in detail and their origins and habitat needs are unknown. Some, especially those targetting pest species associated with rainforest plants, may have followed their hosts from rainforest into crops. Other rainforest predators and parasitoids may have extended their host ranges to include non-rainforest pest arthropods. Rainforest harbours numerous generalist predatory insects, such as species of robber flies and assassin bugs, with potential to act as biocontrol agents in crops (Queensland Museum 2000). Presumably rainforest arthropods are also attacked by numerous native parasitoids but few of these have been documented.

One pest with no known biocontrol insects is a weevil that can cause crop losses of up to 30% in unsprayed orchards. It was first detected in 1994 and assigned to the genus *Sigastus* (Fay *et al*. 2001). Recent taxonomic assessment suggests that this insect may belong to a different genus (Rolf Oberprieler, CSIRO Entomology, Canberra, pers. comm.). A circular egg-laying ‘chew’ mark on the nut, and a hole in the stem of the nut, indicate the presence of this pest (Fig 7).

The tortricid moths, *Cryptophlebia* spp. (Fig. 8) are major pests of macadamias on the Atherton Tableland, requiring repeated applications of broad-spectrum insecticides. Presence of the larva in the nut is indicated by a small hole surrounded by frass on the surface of the nut. Evaluation of a trichogrammatid egg parasite is in progress (Gus Campbell, Horticulture Australia Project MC 99001). A wasp from China, *Elachertus* nr *lateralis* (Spinola), that parasitises tortricid larvae, was released in 1993-4 but its effectiveness is unknown (Waterhouse & Sands 2001).

Fig. 7. Adult 'Sigastus' weevil.
Note egg-laying scar on macadamia nut and hole bored in stem. (Photograph R. Bauer)

Fig. 8. Macadamia nutborer.
Typical frass-covered entry hole indicating the presence of a larva (top inset) inside a macadamia nut. Adult lower inset. (Photograph R. Bauer)

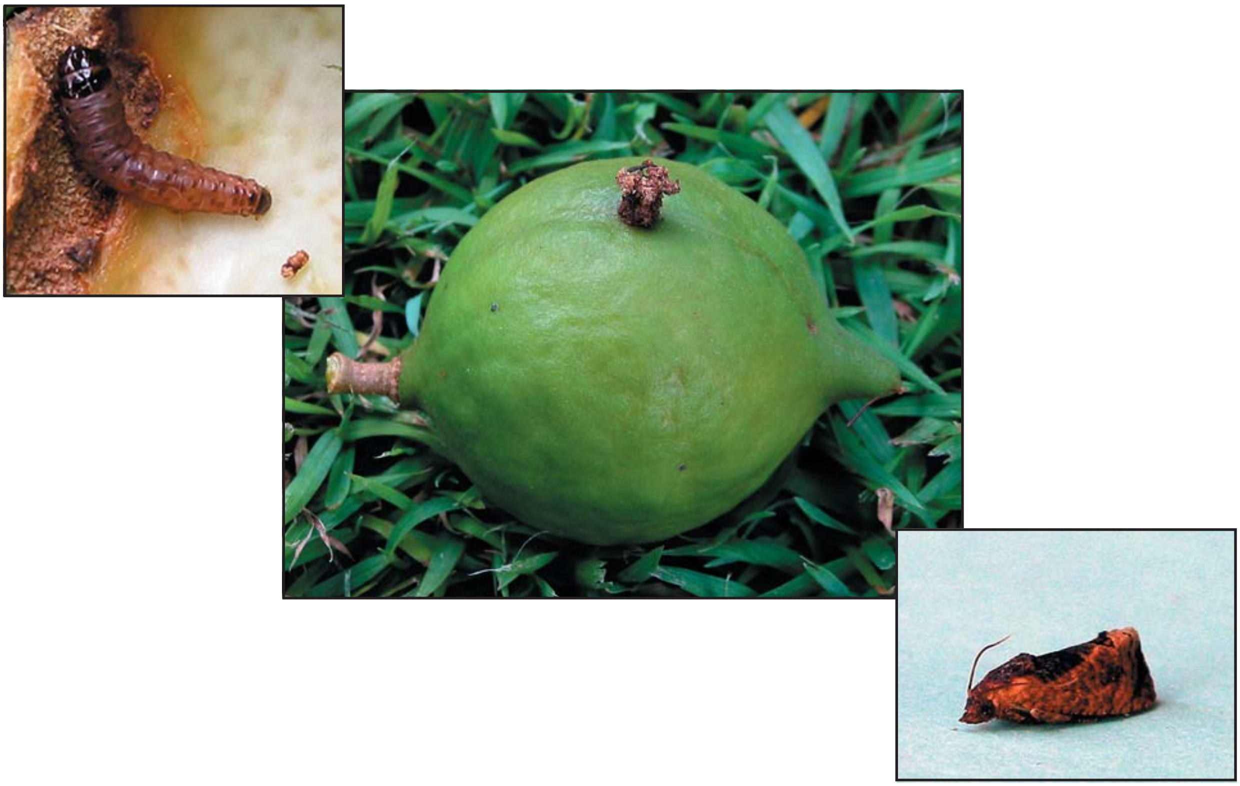


Table 4. Economically important arthropod pests and the main insects known to attack them in the Atherton region.
Compiled from: Broadley 1991; CSIRO 1991; Fay *et al*. 1993; Pinese & Piper 1994; Brough *et al*. 1996; Ironside 1995; Agnew 1997; Smith *et al*. 1997; Malipatil *et al*. 2000; Pinese *et al*. 2001; Waterhouse & Sands 2001.

COMMON NAME	AUSTRALIAN NATIVE PARASITOIDS	AUSTRALIAN NATIVE PREDATORY INSECTS	EXOTIC PARASITOIDS	EXOTIC PREDATORY INSECTS
avocado fruit borer (native)	-	-	Elachertus nr lateralis Spinola (wasp, China)	-
avocado leaf roller (native)	unidentified wasp spp., tachinid fly spp.	unidentified hoverfly larva	-	-
banana rust thrips	-	lacewings, coccinellids, ants	-	-
banana scab moth	unidentified wasps	Tetramorium bicarinatum (Nylander) (ant)	-	-
banana spider mite (native)	-	Stethorus histrio Chazeau (coccinellid)	-	-
banana weevil borer	-	elaterid beetle larva	-	Dactylosternum hydrophiloides (Macleay) (beetle, Malaysia)
banana-spotting bug (native)	Pentatomophaga bicincta de Meijere (tachinid fly), unidentified wasp sp.	Pristhesancus papuensis Ställ (assassin bug)	-	Pheidole megacephala (Fabricius) (ant, Africa?)
bean fly	unidentified wasp spp.	-	-	-
cane weevil borer	-	-	Lixophaga sphenophori (Villaneauve) (tachinid fly, New Guinea)	-
canegrubs (native)	-	Campsomeris tasmaniensis Saussure, Dielis formosus Guerin-Meneville (wasps), robber flies, elaterid beetle larvae	Microphthalma michiganensis Townsend (tachinid fly, Canada), Campsomeris spp. (wasp, Phillipines)	-
citrus bud mite	-	-	-	-
citrus gall wasp (native)	Megastigmus brevivalvus (Girault), M. trisulcus (Girault) (wasps, cosmopolitan)	-	-	-

citrus mealybug	-	Cryptolaemus montrouzieri Mulsant (coccinellid), lacewings	Leptomastix dactylopii Howard (wasp, Brazil or Africa?)	-
citrus rust mite	-	cecidomyiid fly larvae (cosmopolitan)	-	-
citrus snow scale	-	-	Encarsia citrina (Craw), Aphytis spp. (wasps, China, Japan, Hong Kong, Thailand)	Chilocorus circumdatus Gyllenhal (coccinellid, Hong Kong)
common mango scale	-	-	-	-
corn earworm	numerous wasp and fly spp.	predatory bugs, beetles, lacewings	-	Trichogramma pretiosum Riley (wasp, USA)
ectropis looper (native?)	-	predatory bugs	-	Apanteles spp. (wasp, S America)
erinose mite	-	fly larva	-	-
fruit-piercing moths (native)	Trichogramma spp. (wasps, cosmopolitan), Euplectrus melanocephalus Girault (wasp), Exorista sp. (tachinid fly)	lygaeid bug	Telenomus spp. (wasps, SE Asia, Dominican Rep., Japan), Ooencyrtus spp. (wasps, Trinidad)	-
green coffee scale	-	Cryptolaemus montrouzieri (coccinellid)	Coccophagus spp. (wasps, Japan, Taiwan), Diversinervis spp. (wasps, Uganda, Kenya)	-
hemispherical scale	-	Cryptolaemus montrouzieri (coccinellid), Catoblemma dubia (Butler) (moth larva)	Scutellista caerulea (Fonscolombe) (wasp, S/E Africa?), Encyrtus infelix (Embleton) (wasp, USA, Israel)	Scutellista caerulea (wasp larvae, S/E Africa?)
lacebug (native)	-	-	-	-
latania scale	-	Chrysopa spp. (lacewings), Rhizobius spp. (coccinellid)	Encarsia citrina, Aphytis spp. (wasps, China, Japan, Hong Kong, Thailand)	-
macadamia flower caterpillar (native)	*Agathis rufithorax* Turner, *Brachymeria* sp., *Phanerotoma* sp, *Trichogrammatoidea flava* Nagaraja (wasps)	*Termatophylum* sp. (mirid bug)	-	-

macadamia nut borers (native)	*Apanteles briareus* Nixon, *Bracon* spp., *Gotra bimaculatus* Cheesman (wasps), unidentified tachinid fly sp.	assassin bugs	*Elachertus* nr *lateralis* (wasp, China)	-
macadamia weevil (native?)	-	-	-	-
mango planthopper (native)	*Achalcerinys* sp. (wasp), dryinid wasp spp., strepsiptera spp.	assassin bugs	-	-
mango scale	-	-	-	-
mango seed weevil	-	-	-	-
mussel scale	-	*Halmus chalybeus* (Boisduval) (steel-blue coccinellid)	*Aphytis lepidosaphes* Compere (wasp, China)	-
nigra scale	-	*Cryptolaemus montrouzieri* (coccinellid), *Catoblemma dubia* (moth larva)	*Scutellista caerulea* (wasp, S/E Africa?)	*Scutellista caerulea* (wasp larvae, S/E Africa?)
oriental scale	-	*Chilocorus baileyi* Blackburn (coccinellid)	*Encarsia citrina*, *Aphytis* spp. (wasps, China, Japan, Hong Kong, Thailand), *Comperiella* spp., (wasps, China)	*Chilocorus circumdatus* (coccinellid, Hong Kong)
pink wax scale	*Aenasoidea varia, Rhopalencyrtoidea dubia* (wasps)	*Rhyzobius ventralis* (Erichson), *Cryptolaemus montrouzieri, Diomus* spp., *Harmonia conformis* (Boisduval) (coccinellids), *Catoblemma dubia* (moth larva)	*Anicetus beneficus* Ishii & Yasumatsu (wasp, Japan), *Coccophagus ceroplastae* (Howard) (wasp, Japan, Taiwan)	*Scutellista caerulea* (wasp larvae, S/E Africa?), *Mallada* spp. (lacewings cosmopolitan ?)
potato moth	unidentified wasp spp.	-	*Apanteles subandinus* Blanchard (wasp, S America)	-
Queensland fruit fly (native)	-	Pristhesancus plagipennis Walker (assassin bug), praying mantises	Diachasmimorpha longicaudata (Ashmead) (wasp, SE Asia), Fopius arisanus (Sonan) (wasp, Malaysia)	-
red scale	-	Rhyzobius lophanthae (Blaisdell), Halmus chalybeus (coccinellids)	Encarsia citrina, Aphytis spp. (wasps, China, Japan, Hong Kong, Thailand), Comperiella bifasciata Howard (wasp, China)	Chilocorus circumdatus (coccinellid, Hong Kong), Mallada spp. (lacewings cosmopolitan ?)

redbanded thrips	-	lacewings, predatory thrips, predatory bugs	-	-
redshouldered leaf beetle (native)	Monoleptophaga calwelli Baranov (tachinid fly)	-	-	-
rhinocerus beetle	-	-	-	-
spherical mealybug	-	Cryptolaemus montrouzieri (coccinellid)	Anagyrus agraensis Saraswat (wasp, N Africa ?)	-
spined citrus bug (native)	unidentified tachinid fly sp., Trissolcus oenone (Dodd), Anastatus spp. (wasps)	Pristhesancus plagipennis (assassin bug), praying mantises, predatory bugs, ants, lacewing larvae	-	-
sugarcane budmoth (native)	unidentified wasp sp.		-	-
sugarcane soldier fly (native)	three unidentified wasp spp. (Diapriidae)	predatory beetles (carabids, staphylinids, elaterids)	-	-
swarming leaf beetles (native)	-	-	-	-
sweet potato weevil	unidentified wasp spp.	-	-	Pheidole megacephala (ant, Africa?)
two-spotted mite	-	Stethorus histrio (coccinellid), lacewing larvae	-	Scolothrips sexmaculatus (Pergande) (thrips, ?)
white fringed weevil	-	carabid beetle larvae, horsefly larvae, wireworms (elaterids), ants	-	-
yellow peach moth	Argyrophylax proclinata Crosskey (tachinid fly)	Pristhesancus plagipennis (assassin bug)	-	-

SIGNIFICANCE

This report shows that the relatively small region of the Atherton Tablelands, and adjoining coastal areas, has enormous variation in soil type, elevation, rainfall, temperature and vegetation cover. Apart from the World Heritage Area, only remnants of rainforest remain on the Tablelands. The broad range of cropping systems that has become established is due in part to changing market pressures but also reflects the great environmental diversity.

Like commercial honey bee populations in other parts of the world, honey bees in the Atherton Tableland region may be at risk from habitat loss, pesticide use, parasitism and disease. There is a need to identify alternative pollinators that could replace commercial honey bee pollinators and also to eliminate costly hand-pollination of some crops. Few rainforest insects are reported to be pollinators of crops but there are strong indications that many will prove suitable.

Only nine of 49 major arthropod pests in the region have verified connections with rainforest but it is likely that some others use rainforest plants for at least part of their life cycle. Most insect pests known to be associated with rainforest are difficult to control.

Many insect pests are attacked by parasitoid or predatory insects capable of reducing their numbers. The effectiveness of these natural enemies is limited by lack of knowledge about how to maintain them in crop situations, especially in conjunction with pesticide use. Increasing acceptance of integrated pest management practices and growing public demand for pesticide reduction highlight the need to discover the origins, and consequently the habitat requirements, of parasitoid and predatory insects.

Field studies aimed at addressing the gaps in knowledge identified in this report will allow a more realistic evaluation of the costs and benefits associated with tropical rainforest insects in crops.

REFERENCES

Agnew, J. (ed.) (1997) Australian Sugarcane Pests. BSES, Indooroopilly, Queensland.

Anderson, D. L., Sedgley, M., Short, J. R. T. and Allwood, A. J. (1982) Insect pollination of mango in northern Australia. Australian Journal of Agricultural Research 33, 541-48.

Black, S. H., Shepard, M. and Allen, M. M. (2001) Endangered invertebrates: the case for greater attention to invertebrate conservation. Endangered Species UPDATE 18, 41-9.

Brimblecombe, A. R. (1948) Fruit-spotting bug as a pest of the macadamia or Queensland nut. Queensland Agricultural Journal 1 Oct, 206-211.

Broadley, R. H. (ed) (1991) Avocado Pests and Diseases. Information Series Q190013. QDPI, Brisbane, Queensland.

Brough, E. J., Elder, R. J. and Beavis, C. H. S. (eds) (1996) Managing Insects and Mites in Horticultural Crops. QDPI, Brisbane, Queensland.

Bureau of Meteorology (2001) Climate averages. (Online)
http://www.bom.gov.au/climate/map/climate_avgs/a31.shtml (21 October 2001).

Campbell, T. (1998) Rural development on the Atherton Tablelands: change, choices and challenges. (Online)
http://www.agric.wa.gov.au/programs/new/newrural/T_Campbell.htm (10 December 1998).

Cane, J. H. and Tepedino V. J. (2001) Causes and extent of declines among native North American invertebrate pollinators: detection, evidence and consequences. Conservation Ecology 5, 1. (Online) http://www.consecol.org/vol5/iss1/art81 (2001).

Chudleigh, P. (1999) Review of the prospects for the Australian black tea industry. RIRDC Publication No 99/28 Project No AGT-5A.

Clewett, J. F., Smith, P. G., Partridge, I. J., George, D. A. and Peacock, A. (1999) Australian Rainman Version 3: An integrated software package of rainfall information for better management. Q19807, QDPI, Queensland.

Cosic, M. (2002) Eat, drink and be wary. pp. 23-6 In: The Weekend Australian Magazine, 12-13th January. Nationwide News Pty Ltd, Surry Hills, NSW.

Crosthwaite, I. (1994) Peanut Growing in Australia. QDPI, Brisbane, Queensland. CSIRO. (1991) The Insects of Australia. Melbourne University Press, Carlton, Victoria.

Davenport, T. L., Parnitzki, P., Fricke, S. and Hughes, M. S. (1994) Evidence and significance of self-pollination of avocados in Florida. Journal of the American Society for Horticultural Science 119, 1200-07.

Department of Agriculture Western Australia (1998) Bee pollination benefits for coffee crops. (Online) http://www.agric.wa.gov.au/programs/dairy/apiculture/coffee.htm (24 December 1998).

Department of Agriculture Western Australia (2000) Bee pollination benefits for pumpkin crops. (Online) http://www.agric.wa.gov.au/programs/dairy/apiculture/pumpkin_text.htm (19 January 2000).

Department of Primary Industries Queensland. (1999a) Growing tropical bananas. (Online) http://www2.dpi.qld.gov.au/dpinotes/hortic/tropfruit/h00175.html (July 2000).

Department of Primary Industries Queensland. (1999b) *Centre for Tropical Agriculture Mareeba*. (Booklet) QDPI, Mareeba, Queensland.

Department of Primary Industries Queensland.(2000a) *An Agricultural Profile of the Atherton Tablelands*. QDPI, Mareeba, Queensland.

Department of Primary Industries Queensland. (2000b) The market for organic products. (Online) http://www2.dpi.qld.gov.au/dpinotes/economics/rib00009.html (February 2000).

Department of Primary Industries Queensland. (2001) Bee disease in NQ prompts Bowen identification workshop. (Online) wysiwyg://13http://www.dpi.qld.gov.au/news/NewsReleases/3161.html (February 2001).

Drew, R. A. I., Zalucki, M. P. and Hooper, G. H. S. (1984) Ecological studies of eastern Australian fruit flies (Diptera: Tephritidae) in their endemic habitat. *Oecologia* 64, 267-72.

Eacham Historical Society (1982) *Christie Palmerston Explorer of the Rainforest*. Eacham Historical Society, Atherton, Queensland.

Fay, H. A. C. (1996) Evolutionary and taxonomic relationships between fruit-piercing moths and the Menispermaceae. *Australian Systematic Botany*, 9, 227-33.

Fay, H. A. C., De Faveri, S. G., Storey, R. I. and Watson, J. (2001) *Sigastus* weevil – an emerging pest of macadamias in north Queensland*. Proceedings of the 6th Workshop in Tropical Agricultural Entomology*, Darwin, NT, 11-15 May 1998. NT-DPIF Technical Bulletin No. 288.

Fay, H. A. C. and Huwer, R. K. (1993) Egg parasitoids collected from *Amblypelta lutescens lutescens* (Distant) (Hemiptera: Coreidae) in north Queensland. *Journal of the Entomological Society of Australia* 32, 365-367.

Fay, H. A. C., Storey, R. I., DeFaveri, S. G. and Brown J. D. (1993) Suppression of reproductive development and longevity in the redshouldered leaf beetle, *Monolepta australis* (Col.: Chrysomelidae), by the tachinid, *Monoleptophaga caldwelli* (Dipt.). *Entomophaga* 38, 335-42.

Gazit, S., Galon, I. and Podoler, H. (1982) The role of nitidulid beetles in natural pollination of *Annona* in Israel. *Journal of the American Society of Horticultural Science* 107, 849-52.

George, A. P., Nissen, R. J., Ironside, D. A. and Anderson, P. (1989) Effects of nitidulid beetles on pollination and fruit set of *Annona* spp. hybrids. *Scientia Horticulturae* 39, 289-99.

Gibbs, D. M. H. and Muirhead, I. F. (1998) *The Economic Value and Environmental Impact of the Australian Beekeeping Industry*. Report prepared for the Australian beekeeping industry.

Graham, A. W., Hopkins, M. S. and Maggs, J. (1995a) Succession and disturbance in the remnant rainforest type complex notophyll vine forest on basalt (type 5b).*Report for the Wet Tropics Management Authority*, CSIRO, Atherton, Queensland.

Graham, A. W., Hopkins, M. S. and Maggs, J. (1995b) Succession and disturbance in the remnant rainforest type complex mesophyll vine forest on basalt (type 1b). *Report for the Wet Tropics Management Authority*, CSIRO, Atherton, Queensland.

Hansman, D. J. (2001) Floral biology of dry rainforest in north Queensland and a comparison with adjacent savanna woodland. *Australian Journal of Botany* 49, 137-53.

Heard, T. A. (1993) Pollinator requirements and flowering patterns of *Macadamia integrifolia*. *Australian Journal of Botany* 41, 491-97.

Heard, T. A. (1994) Behaviour and pollinator efficiency of stingless bees and honey bees on macadamia flowers. *Journal of Apicultural Research* 33, 198-98.

Heard, T. A. (1999) The role of stingless bees in crop pollination. *Annual Review of Entomology* 44, 183-206.

Heard, T. A. and Exley, E. M. (1994) Diversity, abundance and distribution of insect visitors to macadamia flowers. *Environmental Entomology* 23, 91-100.

Hopper, S. D. (1980) Pollination of the rainforest tree *Syzygium tierneyanum* (Myrtaceae) at Kuranda, north Queensland. *Australian Journal of Botany* 28, 223-37.

House, S. M. (1989) Pollen movement to flowering canopies of pistillate individuals of three rainforest tree species in tropical Australia. *Australian Journal of Ecology* 14, 77-94.

Ironside, D. A. (1995) *Insect Pests of Macadamia*. QDPI, Brisbane, Queensland.

Irvine, A. K. and Armstrong J. (1988) Beetle pollination in Australian tropical rainforests. *Proceeding of the Ecological Society of Australia* 15, 107-13.

Kevan, P. G. and Phillips T. P. (2001) The economic impacts of pollinator declines: an approach to assessing the consequences. *Conservation Ecology* 5, 8 (Online) http://www.consecol.org/vol5/iss1/art8 (2001).

Malipatil, M. B., Dunn, K. L. and Dmith, D. (2000) *An Illustrated Guide to the Parasitic Wasps associated with Citrus Scale Insects and Mealybugs in Australia*. Department of Natural Resources and Environment, Knoxfield, Victoria.

McConchie, C. A. and Batten, D. J. (1989) Floral biology and fruit set in lychee. *Proceedings of the Second National Lychee Seminar*, pp.71-4. Cairns, Australia.

Morrisen A. (1995) The pollination biology of papaw (*Carica papaya* L.) in central Queensland. Unpublished PhD Thesis, Central Queensland University.

Nadel, H and Peña, J. E. (1994) Identity, behaviour and efficacy of nitidulid beetles (Coleoptera: Nitidulidae) pollinating commercial Annona species in Florida. *Environmental Entomology* 23, 878-86.

Peña, J. E., Mohyuddin, A. I. and Wysoki, M. (1998) A review of the pest management situation in mango agroecosystems. *Phytoparasitica* 26, 1-20

Pinese, B., Bauer, R. and Horak, M. (2001) *Avocado Pest Monitoring on the Atherton Tableland*. Final Report HRDC Project AV99006. QDPI, Mareeba, Queensland.

Pinese, B. and Piper, R. (1994) *Bananas, Insect and Mite Management*. QDPI, Brisbane, Queensland.

Queensland Museum. (2000) *Wildlife of Tropical North Queensland*. Queensland Museum, South Brisbane, Queensland.

Rashad, S. E., Ewies, M. A. and El Rabie, H. G. (1979) Pollinators of peanut (*Arachis hypogaea* L.) and the effect of honeybees on its yield. *Agricultural Experimental Station Special Miscellaneous Publication* 1, 227-30

Ridgeway, R. (ed) (1989) *Mango Pests and Disorders*. Information Series Q189007. QDPI, Brisbane, Queensland.

Robertson, L. N., Allsopp, P. G., Chandler, K. J. and Mullins, R. T. (1995) Integrated management of canegrubs in Australia: current situation and future research directions. *Australian Journal of Agricultural Research* 46, 1-16.

Robertson, L. N. and Webster, D. E. (1995) Strategies for managing cane weevil borer. *Proceedings of the Australian Society of Sugarcane Technologists* 17, 83-7.

Sallam, M. N. and Garrad, S. W. (2001) Distribution and sampling of adults of *Rhabdoscelus obscurus* (Boisduval) (Coleoptera: Curculionidae) and their damage in sugarcane. *Australian Journal of Entomology* 40, 281-285.

Sanford, M. T. (1992) Pollination of citrus by honey bees. (Online)
http://edis.ifas.ufl.edu/BODY_AA092 (December 1992).

Sinclair, E. R. (1979) Parasites of *Cryptophlebia ombrodelta* (Lower) (Lepidoptera: Tortricidae) in southeast Queensland. *Journal of the Australian Entomological Society* 18, 329-335.

Smith, D., Beattie, G. A. C. and Broadley, R.(eds) (1997) *Citrus Pests and Their Natural Enemies*. QDPI & HRDC, Brisbane, Queensland.

Vithanage, V. and Ironside D. A. (1986) The insect pollinators of macadamia and their relative importance. *The Journal of the Australian Institute of Agricultural Science* 52, 155-60.

Waite, G. K. (1988) Biological control of latania scale on avocados in south-east Queensland. *Queensland Journal of Agricultural and Animal Sciences* 45, 165-167.

Waite, G. K. and Huwer, R. K. (1998) Host plants and their role in the ecology of the fruitspotting bugs *Amblypelta nitida* Stal and *Amblypelta lutescens lutescens* (Distant) (Hemiptera: Coreidae). *Australian Journal of Entomology* 37, 340-349.

Walker D. (ed) (1979) Vegetation history of the Atherton Tablelands. (Online)
“http://rainforest-australia.com/vegetation_history_of_the_athert..htm” (1 September 1979).

Waterhouse, D. F. and Sands, D. P. A. (2001) *Classical Biological Control of Arthropods in Australia*. ACIAR Monograph No. 77, Canberra, ACT.

Winter, J. W., Bell, F. C., Pahl, L. I. and Atherton, R. G. (1987) Rainforest clearfelling in northeastern Australia. *Proceedings of the Royal Society of Queensland* 98, 41-58.