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Front Cover: Mating pair of flower wasps *Zaspilothynnus nigripes* at inflorescence of *Hakea trifurcata* (Proteaceae) with the winged male (above) covered in pollen and feeding the female by regurgitating nectar. (Keith Smith)

Back Cover: Chick of Chestnut-backed Button-quail (*Turnix castanonotus*) at Cobourg Peninsula. (Stuart Young)

NORTHERN TERRITORY NATURALIST

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Editorial

Publication of this 25th issue of *Northern Territory Naturalist* should prompt us, as a club, both to celebrate this achievement and to reflect on the purpose and direction of our journal.

Human influences are very rapidly changing the unique natural environments of the wet/dry tropics of northern Australia. Everywhere we see canalisation and control of waterways, conversion of woodlands to grasslands, and reclamation and modification of coasts. Such altered environments result in changed plant and animal communities, often dominated by opportunistic, cosmopolitan, weed or pest species. These changes are accompanied by declines in populations of localised species, and, increasingly, extinctions of entire species. Developers dismiss such changes as inevitable, and as localised collateral damage from the intangible 'progress', but the outcome is a tragedy for the entire planet. It is not unreasonable to predict a time when whole groups of northern Australian species can only be described scientifically from their dead remains from the bank in the soil because of the mass extinctions that went largely unrecognised and undocumented.

We may come across the signposts of such changes serendipitously during our field trips, or even in our own backyards. We should not only write down our observations, but also publish them so that they can be included as pieces in the jigsaw of anthropomorphic and climate change. Some of the species presently invading northern Australia, like Gamba Grass (*Andropogon gayanus*), have the capacity in their own right to change the environment drastically and irrevocably, whereas others may prove to be relatively innocuous. We may not be able to tell the difference when we first encounter exotic species in the wild, so we must introduce them only with the utmost caution, if at all. Amongst the recent invaders that now call the 'Top End' home, and that could have been monitored more closely, are Cane Toads (*Rhinella marina*; formerly *Bufo marinus*), Siamese Fighting Fish (*Betta splendens*), Tawny Coster butterflies (*Acraea terpsicore*), Gamba Grass, and Brazilian Joyweed (*Alternanthera brasiliana*).

Our journal, the *Northern Territory Naturalist*, deserves a string of accolades. Since the first issue in June 1978 it has evolved into an authoritative, registered, peer-reviewed and widely disseminated publication. It results from a symbiosis between amateur and professional members of the Northern Territory Field Naturalists' Club and enables non-professionals to be mentored by experienced professionals keen to support local scientific recording and advances in knowledge. The continuation of editorial scientific rigour and high standards of writing will ensure the articles are of high quality and ongoing usefulness. Conservation of the natural environments of northern Australia will be assisted by input from the wide range of observers who appreciate, and spend time in, the bush.

Richard C. Willan
Chief Editor

First report of a lacaziosis-like disease (LLD) observed in the Australian Snubfin Dolphin (*Orcaella heinsohni*) in Darwin Harbour, Northern Territory, Australia

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Abstract

A lacaziosis-like disease (LLD) was photographed on the skin of three Australian Snubfin Dolphins (*Orcaella heinsohni*) in Darwin Harbour in 2008 and 2010, and this represents the first report of the skin disease recorded in Australia on this species of dolphin. Lacaziosis-like disease is considered non-lethal, but it could be indicative of decreasing water quality and/or exposure to potentially immunosuppressive anthropogenic or environmental pressures. Photo-identification data provides an efficient and cost-effective approach for documenting the occurrence of LLD and monitoring for the prevalence and incidence of skin lesions in a dolphin population.

Lacaziosis and lacaziosis-like disease (LLD) (the term used for skin disease that is morphologically similar or identical to lacaziosis, but for which a definitive diagnosis is missing) is a chronic mycotic disease which affects humans and dolphins (Hart *et al.* 2011). Lacaziosis is caused by the fungus *Lacazia loboi* (Hart *et al.* 2011), while LLD and skin lesions may be caused by viruses, bacteria, fungi and protozoans (Van Bressem *et al.* 2008). Causes could include potential human pathogens such as poxvirus and herpesvirus (Hart *et al.* 2012).

As part of a photo-identification study of coastal dolphins in Darwin Harbour conducted between 2008 and 2010 (Palmer 2010), LLD skin lesions were photographed on three individual Australian Snubfin Dolphins (*Orcaella heinsohni*) (hereafter referred to as Australian Snubfin); one individual on 28 March 2008, and two individuals on 22 March 2010 (Figures 1, 2). These are the first cases of LLD documented in the Australian Snubfin in Australia. There has been one unpublished observation of this disease in an Australian Snubfin in Queensland (Danielle Cagnazzi,

Figures 1, 2. Photographs showing extensive lacaziosis-like disease on the upper right side of the body (Figure 1), and back and dorsal fin (Figure 2) in an adult Australian Snubfin Dolphin (*Orcaella heinsohni*), Darwin Harbour, 22 March 2010. (Carol Palmer)

pers. comm.), and another in an Irrawaddy Dolphin (*Orcaella brevirostris*) in India (Guido Parra, pers. comm.). Generally, LLD is an emerging infectious disease that is known to occur in South America (Van Bressem *et al.* 2009) and lacaziosis itself has been reported in Bottlenose Dolphins (*Tursiops truncatus*) and Guiana Dolphins (*Sotalia guianensis*) (de Vries & Laarman 1973; Caldwell *et al.* 1975; Simões-Lopes *et al.* 1993; Reif *et al.* 2006, 2009; Van Bressem *et al.* 2009; Kiszka *et al.* 2009).

Photo-identification data provides an efficient and cost-effective approach to documenting the occurrence of skin lesions in free-ranging dolphin populations (Hart *et al.* 2012). Tracking the progress of skin lesions within an individual over time may be symptomatic of the overall health of that individual (Hart *et al.* 2012); moreover, monitoring for increasing prevalence and incidence of skin lesions in a population over time may be indicative of decreasing water quality and/or exposure to potentially immunosuppressive anthropogenic or environmental threats (Hart *et al.* 2012).

The only way to confirm the cause of any skin disease is by histological examination of biopsy samples from stranded animals. Lacaziosis and LLD have zoonotic potential (a zoonosis is a disease transmitted, sometimes by a vector, from a non-human species to humans). It is therefore essential that any person handling samples or affected animals uses the appropriate personal protective equipment and techniques (Van Bressem *et al.* 2009).

Acknowledgements

The project would never have been possible without the tremendous support of friends and colleagues from the Flora and Fauna Division and a host of volunteers who assisted in the boat-based surveys. Research was carried out under permits from the Parks and Wildlife Service of the Northern Territory (33840) and Charles Darwin University Animal Ethics Committee (A06018).

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A bird in the hand is not always easily identified: Description of downy chicks of Chestnut-backed Button-quail (*Turnix castanotus*) from Cobourg Peninsula, Northern Territory, Australia

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Abstract

A clutch of four downy button-quail chicks was captured in a pitfall trap on Cobourg Peninsula, without an adult bird to aid identification. We believe they were Chestnut-breasted Button-quail and provide a description and reasons for this identification.

During a pitfall-trapping survey for small mammals in eucalypt forests and woodlands of Garig Gunak Barlu National Park (Cobourg Peninsula) in June 2010, four button-quail chicks were trapped in one pitfall. Pits were 60 cm deep, 28 cm diameter at the surface and were set in two lines of ten pits, 10 m between pits and with a 30 cm high, 100 m long drift fence connecting the pits along each line (Ward 2009). The pitfall was empty when checked in the late afternoon (c. 17.30 hr) and the chicks were found in the traps when cleared the following morning (c. 07.30 hr). The presence of only three toes on each foot confirmed that these chicks were button-quails (family Turnicidae). No adult button-quails were seen at the site over the four nights of trapping there, but three species occur in the wetter parts of the Top End – Red-backed Button-quail (*Turnix maculosus*), Red-chested Button-quail (*T. pyrrhothorax*), and Chestnut-backed Button-quail (*T. castanotus*). This note sets out why we believe these chicks belonged to the latter species, and provides the first known detailed description of downy chicks of this species.

The chicks had only downy feathers, had open eyes and two of the four retained an egg tooth (Figure 1). The dorsal body surface was orange-red with a prominent pale-edged rufous-brown mid-dorsal stripe from nape to rump. The upper left and right sides of the neck and mantle were unfeathered but the mid-mantle and back were covered in down. The ventral body surface was a light grey-cream colour. The background colour of the head was intermediate between the orange-red and rufous tones of the body, and the head bore three prominent white stripes:

one central stripe started from the lores either side of the bill, met at the forecrown and extended over the crown to the nape; two stripes, one on either side of the head, started from the lores, passed over the eyes and extended back to the neck (Figure 2); and two less prominent white lines started at the gape on each side and passed back under the ear openings. Creamy-white downy feathers covered the lores, and under the chin was white. The eye was solid dark. The skin was black and the beak was black above (egg tooth white if present) and dark with a maroon tinge below. The feet were pale yellow. Measured lengths were: head plus bill 20.5 mm, bill 6.0 mm, tarsus 14.6 mm and middle toe (without claw) 11.3 mm.

To identify the species, comparisons were made with the text descriptions in Marchant & Higgins (1993) of chicks of the three button-quail species recorded from the Top End. The description of the downy chicks of Chestnut-backed Button-quail is the least defined of the three and is quoted below in its entirety. For the other two potential species, what follows are abridged versions of the descriptions with characters that do not match marked in *italics*, and characters that we observed marked in parentheses with **bold type** highlighting characters contrary to the description:

Chestnut-backed Button-quail:

". . . brown-rufous above, with central and lateral pairs of cream stripes; paler cream below'. Source of this description is unknown and there is no other information available" (Marchant & Higgins 1993: 443, citing Schodde & Tidemann 1986).

Red-chested Button-quail:

Downy young. Head and neck: hindneck and top of head *brown* (**orange-red to rufous**), *scattered cream tips causing greyish tinge* (**not evident**). Top of head boldly patterned by white median stripe running from *centre of crown* (**forecrown**) to hindneck, and by broad white supercilium, about width of eye, that runs from the lores to *curl downwards behind the* ear (**continues to the nape, does not curl downwards**). Borders of median crown stripe *and upper margins of supercilium*, broadly bordered with black-brown (some darker edging to crown stripe) (**supercilium white**). Upperparts: *mantle unfeathered*, usually concealed by down of wing pads and hindneck (upper left and right sides of mantle without down, **mid-mantle and rest of back covered by down**).

Red-backed Button-quail:

Head and Neck: *dark grey-brown* (**orange-red to rufous**) with black-brown stripe from centre of forecrown to base of bill. On nape, sides of crown and behind ear, *strands of down have off-white to buff tips* (**prominent white stripes present on head**).

Figure 1. One of four button-quail chicks caught in a pitfall trap on Cobourg Peninsula, June 2010 (MAGNT T.5756). (Stuart Young)

Figure 2. Dorsal view of one of four button-quail chicks caught in a pitfall trap on Cobourg Peninsula, June 2010 (MAGNT T.5756). Note the white egg tooth at the tip of the upper bill and the prominent white stripes on the head. (Simon Ward)

Marchant & Higgins (1993) include pictures of chicks in their colour plates of Red-chested and Red-backed Button-quail and Simpson & Day (1996) provide black and white sketches of hatchlings of these species. Neither reference depicts the hatchlings or chicks of Chestnut-backed Button-quail. The pale striping on the head and body appears most striking in the pictures of the Red-chested Button-quail, whilst the Red-backed Button-quail is depicted as being relatively unmarked. The strong pattern of striping on the heads of the chicks caught at Cobourg Peninsula lead us to conclude that they were not chicks of the Red-backed Button-quail. The description of the chicks of Red-chested Button-quail summarised above is the most detailed, and several features of the Cobourg chicks do not match that description. The species occurs on Cobourg Peninsula, but there have been only two recorded sightings there – in 2004 and 2007 (*NT Fauna Atlas*, Department of Land Resource Management, unpubl.). Consequently, we do not believe the Cobourg chicks were Red-chested Button-quail. This leads us to the conclusion that the chicks we caught were Chestnut-backed Button-quail.

The Chestnut-backed Button-quail has a disjunct distribution in the Top End and the Kimberley region. Its preferred habitat is grassy eucalypt woodlands, often on sandy or rocky ridges. It can be locally common but is an infrequently recorded species and is listed as Data Deficient in the Northern Territory (DLRM 2012). There are 124 records of the species since 1970 in the *NT Fauna Atlas* and six of these are from Cobourg Peninsula. There are previous records of Chestnut-backed Button-quail within approximately 2 km of the location where we caught our chicks (A. Stewart, pers. comm.).

Chestnut-backed Button-quail have been recorded breeding from December to May (Schodde & Tidemann 1986), these months constituting the wet season and early dry of northern Australia. Schodde & Tidemann (1986) describe a typical clutch size of four and give a description of the nest and eggs. Our observations of four recently-hatched chicks in late June indicate that breeding may extend later into the dry season than previously described.

This is but a brief note describing the chicks of what we believe was the Chestnut-backed Button-quail. However, much more detail of the species' breeding ecology remains to be observed and discovered.

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The occurrence of the Asian subspecies of the Gull-billed Tern (*Gelochelidon nilotica affinis*) in the Darwin region, Northern Territory

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Abstract

The Asian subspecies *Gelochelidon nilotica affinis* of Gull-billed Tern breeds in Asia and migrates to northern Australia during its non-breeding season, which is the Australian wet season/summer. A substantial non-breeding population of this tern occurs in northwestern Australia and it is also an uncommon but regular visitor to the northern coasts of Queensland. However, *G. nilotica affinis* remains infrequently reported in the Top End. This fact has prompted us formally to report its occurrence in the Darwin region. Interestingly, our own and other recent reports fall outside its normal wet season/summer visiting period in northern Australia. We comment on the importance of recognising and recording this migratory tern, which is separable from the Australian-breeding subspecies (*G. affinis macrotarsa*) with some care in the field, and include some guidelines to identification of these terns in the field.

The Gull-billed Tern (*Gelochelidon nilotica*) is a large tern belonging to the family Sternidae. The Australian-breeding subspecies (*G. nilotica macrotarsa*) is widespread throughout Australia and breeds on inland wetlands, lagoons, swamps and lakes (Higgins & Davies 1996). Resident *G. nilotica macrotarsa* is nomadic in its range and is an opportunistic breeder, with breeding influenced by rainfall events inland across the continent. During the non-breeding periods, Gull-billed Terns frequent the coastlines of Australia. In northern Australia there is significant overlap of *G. nilotica macrotarsa* with the Asian-migrant subspecies *G. nilotica affinis*. When coastal, these two subspecies have similar daily routines to migratory shorebirds – feeding over mudflats during low tide, and roosting (not restricted to typical shorebird roosts) during high tide.

The Asian subspecies is a migrant to northern Australia and occurs along coastlines during the Austral summer (the wet season), its non-breeding season. Extralimital records of *G. nilotica affinis* are from southeastern Queensland (Higgins & Davies 1996), New South Wales (James 2011) and Victoria (Carter 2011).

Rogers (2004) speculated that northern Australia could be a major non-breeding area for *G. nilotica affinis*, and this has subsequently been confirmed. *Gelochelidon nilotica affinis* and *G. nilotica macrotarsa* are routinely identified to subspecies level in the course of regular shorebird surveys of Eighty Mile Beach and Roebuck Bay, and between them these regions regularly hold more than 1000 *G. nilotica affinis* (Rogers *et al.* 2009; Danny Rogers, pers. comm.). Sparse but regular sightings have also been reported from Cairns, but attention has been drawn to the fact that few reports seemed to exist for the Top End (Denning 2011).

There are previous records of *G. nilotica affinis* in the Top End. It was recorded in small numbers in the Darwin area between September and April during the years 1974 to 1980 (McKean 1981). Schodde (1991) reported that specimens were collected from the East and South Alligator Rivers in February 1973 and October 1974, respectively.

The Gull-billed Tern is easily recognised in the field as a large white tern, with a thick black gull-like bill, white above and below, rather long black legs by tern standards, and pointed wings (Higgins & Davies 1996). The Australian subspecies (*G. nilotica macrotarsa*) (Figure 1a) boasts a black cap during the breeding season, with some streaking of the crown usually remaining during the non-breeding season. The Asian subspecies (*G. nilotica affinis*) (Figure 1b) has slightly darker grey back and tail. It is smaller overall, and has a chisel-shaped bill, whereas *G. nilotica macrotarsa* has a proportionately longer bill and slightly drooped tip (Rogers 2004; Figures 1 and 2).

Note, with reference to Figure 2, that when individuals of both subspecies are seen side by side in the field, the smaller size of *G. nilotica affinis* is very obvious. Importantly, *G. nilotica affinis* has a broken black eye-mark, with a black spot around the eye, and another on the ear-coverts; they can be narrowly joined. By contrast, *G. nilotica macrotarsa* has a large continuous black mark from the eye to the ear covert. *Gelochelidon nilotica affinis* has a white lower eyelid, which aids in the division of the black marking between the eye and the ear covert (Rogers 2004). Note also the difference in the shape and size of the bill, and the darker upper parts of *G. nilotica affinis*. The clean white cap is typical of *G. nilotica affinis*, but quite uncommon in *G. nilotica macrotarsa*, which often has black speckling in the crown in non-breeding plumage (Figure 1).

In breeding plumage *G. nilotica affinis* is black-capped, and less easily distinguished from *G. nilotica macrotarsa*. However the timing of pre-breeding moult can often be helpful in identification. The Asian subspecies, a trans-equatorial migrant, is in non-breeding plumage for most of the time in Australia, with breeding plumage only likely to be seen in adults in March or April (just before its northwards migration). In contrast, breeding plumage can be seen in some Australian Gull-billed Terns in all months.

Figure 1. Gull-billed Terns in non-breeding plumage, Lee Point beach, August 2013: **a.** Two individuals of Australian subspecies (*Gelochelidon nilotica macrotarsa*); **b.** Two individuals of Asian subspecies (*G. nilotica affinis*). (Bastiaan J. Hensen)

Figure 2. Terns in non-breeding plumage, Lee Point beach, August 2013: Individual of Asian subspecies (*Gelochelion nilotica affinis*) in right foreground; individual of Australian subspecies (*Gelochelion nilotica macrotarsa*) in left foreground; individual of Caspian Tern (*Hydroprogne caspia*) in background. (Bastiaan J. Hensen)

To date, there has been no genetic work done on the subspecies of Gull-billed Terns that occur in Australia, however Rogers *et al.* (2005) suspect that if DNA analyses were performed, *G. nilotica affinis* would be resolved as a separate species. The purpose of this short note is to raise awareness of the Asian subspecies in the Northern Territory, and to increase the reporting rate of this migratory tern by field observers. Birdwatchers may be interested in an 'armchair tick' in the instance that *G. nilotica affinis* is indeed awarded full-species status.

Some recent observations of *G. nilotica affinis* in the Darwin region have been made on the northern beaches of Darwin (Table 1). Note that the sightings are outside the normal migratory summer (September–April) season, and as such are of particular interest.

Table 1. Compilation of reports of Gull-billed Terns in the Darwin region, Northern Territory.

Date	Location	Reference (comment)
10/1974	South Alligator River	Report by Schodde (1991) (*G. nilotica affinis*) (specimen collected)
1989	Leanyer Sewage Ponds	Hillary Thompson (*G. nilotica affinis*) (specimen collected)
31/10/1998	Leanyer Sewage Ponds	Niven McCrie (11/12 birds were *G. nilotica affinis*)
11/03/2005	Lee Point	Bastiaan Hensen (*G. nilotica affinis*)
24/03/2005	Lee Point	Bastiaan Hensen (*G. nilotica affinis*)
2/10/2005	Lee Point	Arthur and Sheryl Keates (1 *G. nilotica affinis*)
16/10/2005	Lee Point	Arthur and Sheryl Keates (2 *G. nilotica affinis*)
1/11/2005	Lee Point	Arthur and Sheryl Keates (2 *G. nilotica affinis*)
21/10/2006	Lee Point	Arthur and Sheryl Keates (2 *G. nilotica affinis*)
4/11/2006	Lee Point	Arthur and Sheryl Keates (2 *G. nilotica affinis*)

(continued)

Table 1. Continued.

Date	Location	Reference (comment)
28/09/2008	Lee Point	Arthur and Sheryl Keates (1 *G. nilotica affinis*)
29/09/2008	Lee Point	Arthur and Sheryl Keates (2 *G. nilotica affinis*)
13/10/2008	Lee Point	Arthur and Sheryl Keates (1 *G. nilotica affinis*)
20/09/2009	Lee Point	Arthur and Sheryl Keates (1 *G. nilotica affinis*)
25/09/2009	Lee Point	Arthur and Sheryl Keates (2 *G. nilotica affinis*)
11/03/2011	Lee Point	Bastiaan Hensen (*G. nilotica affinis*)
14/10/2011	Leanyer Sewage Ponds	Bastiaan Hensen (*G. nilotica affinis*)
21/05/2013	Leanyer Sewage Ponds	Gus Daly (sighting of both subspecies, reported on Eremaea)
26/05/2013	Leanyer Sewage Ponds	Gus Daly (sighting of both subspecies, reported on Eremaea)
4/07/2013	Leanyer Sewage Ponds	Gus Daly (sighting of both subspecies, reported on Eremaea)
5/07/2013	Leanyer Sewage Ponds	Gus Daly (sighting of both subspecies, reported on Eremaea)
12/08/2013	Lee Point	Amanda Lilleyman and Bastiaan Hensen (sighting of both subspecies) (see Figures 1, 2)

We believe that with some care, field observers can readily distinguish the two subspecies of Gull-billed Terns occurring in the Darwin region, thus facilitating a more thorough investigation of population size and regional distribution of both of them.

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Management of Brazilian Joyweed (*Alternanthera brasiliana*) in the Casuarina Coastal Reserve, Darwin, Australia

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Abstract

For the past 20 years, the only locality in the Darwin region in which Brazilian Joyweed (*Alternanthera brasiliana*) has been recorded outside cultivation is the Casuarina Coastal Reserve. This article documents its recent proliferation as 'spot fires' in disturbed and undisturbed woodland habitats in the central western section of the Coastal Reserve, as well as its spread to woodland at Charles Darwin University's Brinkin campus on the southern extremity of the Coastal Reserve. Both are probably marginal or sub-optimal locations in terms of the species' full range of habitats. This article also profiles Brazilian Joyweed's identifying characteristics and ecology, in particular those aspects that make it an opportunistic invader, and management options in the Coastal Reserve. There, Brazilian Joyweed is spreading, outcompeting native species thereby threatening the ecosystem, and contravening the visual aesthetics of the Reserve. Brazilian Joyweed causes dermatitis and asthma in some people, and is not consumed by – that is, not controlled by – any vertebrate or invertebrate herbivore. These undesirable characteristics, when taken together, render its eradication in the Coastal Reserve and the University campus highly desirable. The populations in both localities should be, and indeed can successfully be, eliminated at the present time. However, the more wet seasons these populations remain unchecked, the harder eradication will become.

Introduction

This article is entirely the product of an amateur botanist driven by curiosity about an intriguing naturalised plant with a propensity for weediness.

Brazilian Joyweed is a member of the family Amaranthaceae in the higher group of flowering plants Magnoliophyta. It is known by a plethora of other common names besides Brazilian Joyweed – Alternanthera, Calico Plant, Indoor Clover, Joseph's Coat, Joy Weed, Large Purple Alternanthera, Metal Weed, Parrot Leaf, Purple Alternanthera, Purple Joy Weed, Purple Joyweed, Ruby Calico Plant and Ruby Leaf. For simplicity, it is henceforth called just Joyweed in this article. Its scientific name is now agreed and accepted as *Alternanthera brasiliana* (L.) Kuntze, however until recently

it was known in the Northern Territory Herbarium's database under its synonym *Alternanthera dentata* (Mönch) Stuehlik ex R. E. Fr.; cultivar rubra (Ian Cowie, pers comm.). This name, or at least just *Alternanthera dentata*, appears in the present Plan of Management for the Casuarina Coastal Reserve (Parks and Wildlife Commission of the Northern Territory 2002: Appendix 2).

Joyweed is native to (i.e. its original geographical range encompasses) southern Mexico, Central America (i.e. Belize, Guatemala and Nicaragua), the Caribbean and tropical South America (i.e. French Guiana, Guyana, Surinam, Venezuela, Brazil, Colombia, Ecuador and eastern Peru). Some reports state that, besides tropical America, it is also "native to tropical and subtropical regions of Australia" (e.g. Kumar *et al.* 2011: 41–43), but that statement is completely incorrect (Barker & Telford 2013). The error might have originated through confusion of the terms native and naturalised by scientists whose first language is not English. I am unable to track down the original source of this error, but it certainly should not be perpetuated. Joyweed has been widely transported by humans and cultivated beyond its original range, and is now naturalised (technically botanists use this term to mean this species has demonstrated the ability to reproduce in the wild unassisted by humans in places where it has been introduced beyond its original geographical range) in the southeastern United States of America (i.e. Florida), South Africa, India, some Pacific islands (e.g. Hawaii, Niue, Pitcairn Islands, Cook Islands, French Polynesia, and Palau), Singapore (Graham Brown, pers. comm.) and in tropical northern Australia. In tropical northern Australia it now occurs in the Kimberley region and the Top End (i.e. East Alligator River floodplain, Tiwi Islands and coastal communities out to, and including, Alyangula on Groote Eylandt) (Ian Cowie, pers comm.) (Figure 1), as well as northern Queensland. Joyweed is cultivated in a few suburban gardens and schools in the Darwin region, but I have never seen it being sold at the Darwin markets as an ornamental plant or as a herb (pers. obs.). Indeed, it is not recommended by the Nursery and Garden Industry of the Northern Territory because it can quickly spread out of control (Nursery & Garden Industry Australia 2009).

Popular medicine has endowed Joyweed with numerous beneficial properties as treatments for coughs, diarrhoea, inflammation, infections, wounds, tumours, night blindness and hazy vision (Kumar *et al.* 2011). Western literature also demonstrates that Joyweed possesses many pharmacologically active chemicals that provide analgesia, improve wound healing, and have antitumour, immunosuppressant and antimicrobial activity (Kumar *et al.* 2011). Indeed, rigorous scientific experiments have elucidated the compounds responsible for this bioactivity (e.g. Barua *et al.* 2012). On the other hand, there are some negative effects. Contact with the plant causes asthma and dermatitis in some people. I experience dermatitis when brushing my skin against the 'flowers', and interestingly, the symptoms seem to be exacerbated on repeated contact.

Figure 1. Map of the northern half of the Northern Territory showing present distribution of *Alternanthera brasiliana*. Records are indicated by black triangles. Map, based on data in the Northern Territory Herbarium, courtesy Louis Elliott.

Identifying characters

Joyweed is a lax, soft-stemmed, shallow-rooted, perennial herb. It grows in a variety of soil types and habitats. Infestations in the Casuarina Coastal Reserve are most often noticed on the margin of dry woodland where it is conspicuous because of its rich maroon stems/leaves and vivid white 'flowers' (Figures 2–7). However, it can also thrive out of sight under deep shade in closed-canopy forest. In full sun and without support from neighbouring plants, Joyweed grows in a dense monospecific stand seldom exceeding 60 cm high. In contrast, in semi-shade and supported by the introduced Coffee Bush (*Leucaena leucocephala*) and/or the introduced vine Centro (*Centrosema molle*) and/or the native vine Supplejack (*Flagellaria indica*), it grows less densely but considerably taller (up to 2.5 m high). It is claimed it can grow to 4 m overseas (Institute of Pacific Islands Forestry 2010).

The stems (Figures 5, 7) are rounded with longitudinal ridges, and are rich maroon in colour. The nodes are (weakly to strongly) swollen, particularly on older plants, and the internodes are up to 15 cm long. The leaves are arranged on the stem in a decussate arrangement, that is, they are arranged in pairs opposite to those above or

below resulting in four vertical rows. The leaves are soft, simple and shortly petiolate with a distinct dorsal channel. The leaf blades are smooth, lanceolate to ovate, and each is drawn out into a long pointed tip. The leaves are maroon when the plant is growing in full sun, but dull greenish purple when in shade. The main veins on the undersurface of the leaves, including the marginal vein, are rich maroon like the stem, so the undersurface of a leaf looks maroon all over. Microscopic study reveals sparse (20–50 in total per leaf), irregularly scattered, maroon glands confined to the undersurface of the leaves. The stems and leaves have numerous, microscopic, straight (never barbed) white hairs.

The white, pea-sized (0.7–1 cm high) 'flowers', which resemble miniature button chrysanthemums, are the most interesting part of Joyweed because their apparent simplicity belies considerable complexity. The 'flowers' (Figures 6, 7) are really an aggregation of about 60 individual, bisexual, microscopic flowers and accompanying bracteoles. These flowers and bracteoles are arranged in tight, paper-rough, chaff-like groups (botanically correctly called cymes, and that term will be used in this context for the rest of this article with 'flower' referring to the individual flowers constituting the cyme). The cymes are on short stalks in the leaf axils and also on long apical stalks (up to 15 cm long). In other words, they are produced both axially and terminally on the same plant (Figure 3). A very small plant only 30 mm high will sport one single apical cyme (Figure 4).

Two bracteoles are present at the base of the flower (in the proper sense) itself, but they are not actually part of the flower. The bracteoles are stiff, upright, white, hairy, and sharply keeled (3.5 mm in length) with the upper edge jagged like a deeply toothed saw. The flower proper consists of five tepals (whether they are sepals or petals can only be determined by histological investigation so the neutral term 'tepals' is used for them) plus the androecium. The five tepals are identical, stiff, upright, hairy, and they measure 3 mm in length. Taken together, the tepals resemble a newly-opened tulip flower with the tips of the petals almost touching at the top. The androecium consists of five, sharply pointed, pale white staminodes alternating with the brownish, short-stalked anthers (1 mm high) in a zigzag arrangement. The relatively large ovary is unilocular and it is pale green when unripe. As the seed ripens it becomes brown and the surrounding tepals also become dry and brown and quite tough, but they still shroud the brown seed in a 'cocoon'. Eventually the whole flower (i.e. the seed plus the surrounding tepals) falls from the cyme. The bracteoles are not shed and they remain exactly as they were previously whilst other flowers higher up on the cyme become mature.

To test whether Joyweed yields any dyes in polar and non-polar solvents, the author diced stems, leaves and cymes coarsely, and immersed pieces separately in either boiling water or 100% ethanol. Only the stems produced a very pale pink dye after one hour's immersion in boiling water.


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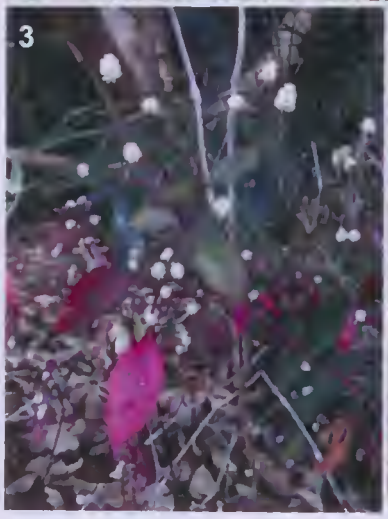
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Figure 2. *Alternanthera brasiliana* growing in partial shade with mature cymes. Note the small clump of Annual Mission Grass (*Cenchrus pedicellatus*) in the bottom right of the photograph. Casuarina Coastal Reserve, June 2013. (Neil Wright)

Figure 3. Single upper stem of *Alternanthera brasiliana* growing in partial shade showing leaves and mature cymes. Note the arrangement of the cymes with axillary ones being predominant on the lower section of the stem and terminal ones being predominant on the upper section of the stem. Charles Darwin University Campus, July 2013. (Neil Wright)

Figure 4. A very small plant of *Alternanthera brasiliana* only 30 mm high produces a single terminal cyme. Casuarina Coastal Reserve, June 2013. (Neil Wright)

Figure 5. When growing in full sun, *Alternanthera brasiliana* drops its leaves in the middle of the dry season as an adaptation to water loss. Casuarina Coastal Reserve, July 2013. (Neil Wright)

Figure 6. The 'flowers' of *Alternanthera brasiliana* consist of densely packed and highly structured groups of real flowers and bracteoles, hence they should be correctly called cymes. Casuarina Coastal Reserve, June 2013. (Neil Wright)

Figure 7. Detail of stem and two axillary cymes of *Alternanthera brasiliana*. Casuarina Coastal Reserve, June 2013. (Neil Wright)

Ecology

The following notes relate to the ecology of Joyweed in the Casuarina Coastal Reserve north of Darwin city. It is perennial, with individual plants living for at least 10 years (my estimation). Joyweed is an extreme opportunist, growing both in full sunshine on the margin of dry woodland and mown areas and under deep shade in closed-canopy forest. Vegetative growth frequently occurs at ground level from the base of the stem to produce a multi-stemmed shrub. The stems can develop adventitious roots from the nodes if they are covered with topsoil. Vegetative regrowth occurs readily from pieces of the stem that accidentally drop onto moist ground during the wet season, but it definitely does not occur during the dry season when the ground is rock-hard. Repeated mowing (or clipping in the case of garden plants outside the Reserve) results in a tight bushy shrub. Like mowing, trampling also induces further regrowth from the base of the stem. I have never seen any (vertebrate or invertebrate) predator eating Joyweed, or any signs of predation. Growth is extremely rapid following the first rain of the build up and during the wet season, but it halts completely during the dry season. Plants drop their leaves in the middle of the dry season, and they then consist only of leggy deep maroon stems supporting numerous white cymes (Figure 5). The full complement of cymes appears early in the dry season (May) and remains fertile throughout the dry season as cycle after cycle of flowers becomes mature within them. The cymes become brittle and detach easily as the dry season progresses (August to November). Therefore, the claim that flowers [i.e. cymes] "are seen throughout the year" (Smith 2011: 57) is certainly incorrect for the plants growing in the Coastal Reserve, though each cyme persists for up to eight months. The toughness of the cymes probably explains why they persist for so long. From my observations it seems that the seeds most often germinate close to the parent plant where they fall in their 'cocoons' composed of tepals, but they are certainly also spread by floodwaters; perhaps the tepalar 'cocoons' are buoyant? The presence of adults does not prevent the germination of seedlings underneath them, so generally several generations will be found growing side by side.

In the Casuarina Coastal Reserve, maximum density of Joyweed is about 100 plants per m^2 and this density is achieved along the margin of the dry woodland forest where it abuts mown areas. In deep shade along freshwater creek banks under the closed canopy of the native Satinash tree (*Syzygium nervosum*) where the ground is moister for longer, the density of Joyweed drops to about 5 plants per m^2. But, as mentioned above, those plants growing in shade can be four times the height of the plants growing in full sun so they have about the same number of cymes. Since no Joyweed plants were observed growing in saline soils as occur at the margins of the tidal creeks that drain into Sandy Creek, I assume it cannot tolerate any salinity.

In the woodland habitats in the Coastal Reserve, disturbance happens every day due to the activities of Orange-footed Scrubfowls (*Megapodius reinwardt*). These strong birds scrape down to 10 cm when foraging and even deeper when tending their massive

communal mounds. So nowhere in the Coastal Reserve can really be considered as undisturbed and thus unable to be colonised by Joyweed. Indeed, the largest patch of Joyweed (approx 0.07 ha in area) lies within the territory of a resident pair of Scrubfowls, and is also less than 200 m away from a massive Scrubfowl mound that is regularly tended by these unrelenting gardeners.

Dry season fires burn stems, leaves and cymes to destruction, but individual Joyweed plants can regenerate from the base of the stem at ground level.

In summary, Joyweed can certainly hold its own with the worst of the environmental weeds in the Casuarina Coastal Reserve. However, as for Lantana (*Lantana camara*) (pers. obs.), I think the Reserve mostly provides sub-optimal habitat for Joybush because of the Top End's extended dry season. During the dry months Joybush makes no vegetative growth and pieces of its stem cannot root if they fall onto the ground. Some Joyweed plants growing in full sunshine certainly do die completely towards the end of the dry season, even after they have dropped their leaves.

Management

The Casuarina Coastal Reserve Landcare Group (CCRLG) was formed in 1998. Its first priority was to remove the invasive weeds that were threatening the natural habitats in the Reserve, particularly the non-declared weed Coffee Bush and the declared weed Candlebush (*Senna alata*). These weeds were targeted for removal around a man-made enlargement of the permanently freshwater uppermost reach of Sandy Creek. This section of the creek receives almost all the stormwater from the suburb of Tiwi through a large drain that runs underneath Rocklands Drive. Following the campaign to remove these weeds during the dry season of 1998 and to replant the area with seedlings of native plants during the following wet season, the rehabilitated area received little attention as the philosophy was to let the native vegetation return on its own accord (Louise Finch, pers. comm.). One large fire devastated the northernmost plantings in 2009 and a smaller fire burnt the margin lightly again in June 2013. There was definitely no Joyweed in the area in 2001 (pers. obs), however when I revisited the area 11 years later (i.e. in June 2012) I discovered one large and dense patch of Joyweed centered at 12.3612°S, 130.8732°E. Searches revealed multiple smaller patches, mostly on the forest margin, southwest of this patch plus half a dozen small patches within small isolated tree 'islands' (mostly consisting of single *Wrightia pubescens* trees) located about 5 m east of these patches, as well as multiple much smaller patches on the forest margin northeast to the CCRLG's 'Moth Block' site at 12.3574°S, 130.8756°E. Therefore, the total linear extent of Joyweed in this section of the Coastal Reserve is presently 0.68 km. Early in 2013, a further two patches were discovered 1 km southwest in woodland at the rear of the Charles Darwin University campus (centered at 12.3680°S, 130.8658°E and at 12.3702°S, 130.8664°E), where it is adjacent to the Coastal Reserve. At the time of writing, I have not undertaken a thorough survey of

the northern section of the Coastal Reserve for Joyweed, so I do not know if there are more patches around Lee Point or Buffalo Creek.

In the central western sections of the Casuarina Coastal Reserve with which I am familiar, the spread of Joyweed is mostly due to transport of seeds (inside their tepalar 'cocoons') when the ground is temporarily flooded during the wet season. However, additional spread has definitely occurred in patches that I liken to spot fires along the margin of the forest. It is likely that seeds are also moved by activities such as mowing and slashing, and even possibly transported by humans and dogs walking through the area. I am certain that no spread of seeds occurs by wind as the reproductive portions (i.e. the cymes themselves and the tepalar 'cocoons') are quite heavy. The question of seed viability remains open. Based on my 2012 trial removal (see below), I had concluded that the seeds can remain viable in the topsoil for no longer than one wet season, but the Internet site *Pacific Island Ecosystems at Risk* contains a communication from the experienced botanist Barbara Waterhouse that the seeds appear to have the ability to remain dormant for a long period (Institute of Pacific Islands Forestry 2010). The matter can be resolved by monitoring the plots in the Coastal Reserve from which flowering plants have been completely removed, which I intend to do.

Joyweed is regarded as an environmental weed in the Northern Territory (Smith 2011), as it is in northern Queensland and northern Western Australia. It has escaped cultivation and become naturalised, particularly along waterways in the warmer and wetter coastal areas of northern Australia. It is included in some environmental weed lists in eastern Queensland (e.g. in Ipswich City and in the Redland Shire) and is regarded as an emerging weed or 'sleeper weed' in the Katherine region (Queensland Government 2011). It is also seen as a threat to native ecosystems on Aboriginal lands in the Northern Land Council area (Smith 2002).

The only locality in the Darwin region at which Joyweed is recorded outside cultivation is the Casuarina Coastal Reserve. Beyond the Coastal Reserve, Joyweed is also recorded from Virginia in the Litchfield Shire (Figure 1; Ian Cowie pers comm., 2013), but the Herbarium's data are not comprehensive. The present Plan of Management for the Coastal Reserve (Parks and Wildlife Commission of the Northern Territory 2002: Section 9.5.3) does include *Alternanthera brasiliana* (under its synonym *A. dentata*) as a weed, but not a declared weed. That Plan aspires to manage the impact of weeds and also to develop strategies to manage weeds.

Despite most of the Coastal Reserve not being an optimal habitat (as argued above) for Joyweed, it is rapidly invading habitats that have been both 'disturbed' by human activities and fire and 'undisturbed' by humans. Its preference for moist soils and for locations alongside freshwater streams – its optimal habitat by my estimate – make it a real worry as it could potentially occupy all such habitats in the Reserve. Indeed, it could be argued that Joyweed has the potential to threaten the ecosystem within the entire Reserve. Observations at the Tiwi site have shown that the patches of dense

Joyweed have prevented the regrowth of seedlings of native plants. Individual plants tolerate fires by resprouting from the base of the stem, so fire is not effective in killing Joyweed. The vivid maroon swathe of Joyweed along the front of the woodland contravenes the aesthetics of the Reserve. On repeated occasions I have come across patches of Joyweed trampled by itinerants as they walk to and from their dry season drinking campsites in the Coastal Reserve, yet on no occasion have I ever seen any indication of them using the plant as a natural medicine. This despite its supposed healing qualities mentioned previously. And lastly, Joyweed is not eaten by or controlled by any (invertebrate or vertebrate) herbivore. All these undesirable attributes render its eradication from the Coastal Reserve and the University campus highly desirable.

Removal of Joyweed from the Coastal Reserve by hand pulling is possible at this time, but it will be a labour intensive and time consuming task. As a trial, a patch of Joyweed of mixed ages approximately 20 m^2 in area that was growing moderately densely in shade besides Tiwi Creek (centered at 12.3611°S, 130.8730°'E) and had definitely never been subject to a targeted or general eradication campaign previously (pers. obs.) was completely removed by careful hand pulling in July 2012. This removal took about six hours of work. The initial removal required follow-up removal of newly-germinated seedlings and resprouted plants (see below) in March 2013, a task that only took one hour. That trial was made easier by the unusually dry wet season of 2012/2013 with almost no flooding, so consequently there was little spread of seedlings from elsewhere. During the trial it was noted that plants that had snapped off at ground level when they were being pulled out (a frequent occurrence) readily resprouted from the base of the stem. Therefore, it is essential to pull the roots out as well as the stems during hand removal.

My observations on Joyweed in the Coastal Reserve can be extrapolated to other localities and parts of Australia with different climatic regimes. I know it is a pessimistic conclusion, but seemingly nothing can control this weed in those tropical and subtropical regions that experience warm climates and moist soils year round!

Acknowledgements

Michael Chaddock and Neil Wright assisted me with the removal of the trial patch of Joyweed in 2012, and Neil kindly took all the photographs for this article. Warm thanks are extended to Ian Cowie (Northern Territory Herbarium) for giving me a practical lesson on the structure of Joyweed 'flowers' and for information from the Northern Territory Herbarium's database on its distribution. Immense thanks are also owed to Louis Elliott (Northern Territory Weed Management Branch) for discussing the technical and legal aspects of 'weeds' in the Northern Territory with me. Louis also kindly provided Figure 1. Maria Wauchope (Senior Park Planner, Northern Territory Parks and Wildlife Commission) provided an electronic copy of the present (2002) Plan of Management for the Casuarina Coastal Reserve.

Michelle Chugg (Nursery & Garden Industry of the Northern Territory) checked the date of publication of the booklet *Grow me instead: a guide for gardeners in Northern Territory* for me. I obtained information on Joyweed in the Darwin region from knowledgeable horticulturist Pat Rasmussen. This article benefitted from comments on earlier drafts by Deborah Hall and Louise Finch (Casuarina Coastal Reserve Landcare Group), as well as my fellow members of the Northern Territory Field Naturalists Club – Louis Elliott, Graham Brown, Don Franklin and Sean Bellairs.

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Remarks on the spatial distribution of some butterflies and diurnal moths (Lepidoptera) in the Top End of the Northern Territory, Australia

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Abstract

The geographical distribution is reviewed and/or new spatial data are given for 15 species of butterflies and diurnal moths from the Top End of the Northern Territory. Three species of day-flying moths, the Zodiac Moth (*Alcides metaurus*) (family Uraniidae), *Mimeusemia centralis* (Noctuidae) and *Euchromia creusa* (Arctiidae), are recorded from the Northern Territory for the first time. Two extant locations of the Purple Beak butterfly (*Libythea geoffroyi*) from Fish River Station and Gregory National Park represent the first confirmed resident breeding populations of this species in the Northern Territory. The Monarch (*Danaus plexippus*) is recorded for the first time from the Top End and western Gulf Country where a large-scale range expansion occurred during April–May 2013; other records from the Darwin area comprise intentional introductions facilitated by 'butterfly releases'. New records of the Plain Tiger (*Danaus chrysippus*) and Northern Argus (*Junonia erigone*) suggest these species have limited ranges in northern Australia; both are considered to be rare vagrants or immigrants from Indonesia, East Timor, or adjacent islands. The White Migrant (*Catopsilia pyranthe*) appears to be a rare seasonal migrant to the Darwin area and nearby locations from further inland. The White-banded Line-blue (*Nacaduba kurava*) is confirmed as occurring in the Darwin area. The Samphire Blue (*Theclinesthes sulpitius*) and the Glistening Line-blue (*Sabulana scintillata*) are newly recorded from the western Gulf of Carpentaria and Gove Peninsula, respectively, extending their distribution considerably further east in the Top End. In contrast, the Plumbago Blue (*Leptotes plinius*) is considered to be erroneous, and accordingly this species is removed from the lepidopteran inventory for the Top End. The Orchard Swallowtail (*Papilio aegeus*), No-brand Grass-yellow (*Eurema brigitta*) and Lurcher (*Yoma sabina*) have narrower ranges within the Northern Territory than previously suspected, being restricted to north-eastern Arnhem Land and/or the Gulf of Carpentaria. Within the Top End, six species, including the Gove Crow (*Euploea alcathoe enastri*), are restricted to northeastern Arnhem Land, but three others, *A. metaurus*, *E. brigitta*, and Red-banded Jezebel (*Delias mysis*), are probably rare vagrants from northern Queensland.

Introduction

The diversity, composition and geographical distribution of butterflies in northern Australia remain poorly known relative to other parts of the continent, such as eastern and southeastern Australia, where there has been a long tradition of effort by collectors. Indeed, the sheer vastness of, and extent of natural vegetation in, the Kimberley and 'Top End', two major subregions of the Australian Monsoon Tropics, coupled with limited access during the wet season, renders northern Australia one of the last frontiers on the continent for lepidopteran research (Braby 2008; Dunn & Franklin 2010; Bisa 2013).

During the course of compiling a critical inventory of butterflies and diurnal moths for this large section of Australia for conservation purposes (M.F. Braby, D. Bisa, D.C. Franklin & S. Keates, unpubl. data), a number of spatial records have come to the author's attention that require comment and clarification. Several of these have already been the subject of intense scrutiny (see Meyer *et al.* 2006; Braby 2008, 2012a), such that five species recorded from the Top End (*Oriens angustulus, Pseudoborbo bevani, Telicota mesoptis, Deudorix diovis, Theclinesthes onycha*), three species from the Kimberley (*Delias mysis, Danaus plexippus, Theclinesthes serpentatus*), plus a further two species from the Kimberley–Top End (*Pelopidas agna, Telicota ancilla*) have been removed from the inventory. This was because the records were deemed to be in error, either comprising misidentifications (determination errors), or mislabelling (transcription errors), or there was doubt regarding their authenticity with insufficient evidence provided to substantiate their presence. In another case, the taxon *Telicota ancilla baudina* proved to be a junior synonym of *T. augias krefftii* (Braby 2012a).

The aim of this article is to clarify the spatial distribution of a further four species of butterflies (*Papilio aegeus, Eurema brigitta, Yoma sabina, Leptotes plinius*) in the Top End for which there is considerable uncertainty. In addition, new spatial data are provided for 11 species of butterflies and diurnal moths in the Top End (*Alcides metaurus, Mimeusemia centralis, Euchromia creusa Catopsilia pyranthe, Libythea geoffroyi, Danaus chrysippus, D. plexippus, Junonia erigone, Nacaduba kurava, Theclinesthes sulpitius, Sabulana scintillata*), three of which represent new occurrences in the Northern Territory. During the course of conducting field work in the Top End over the past decade the author has discovered a number of new localities for species, particularly from the more remote areas. The purpose of this article, however, is not so much to document all of these 'range extensions' but to highlight and critically assess some of the more significant records. The compilation also includes two recent records which comprise new species records for the Northern Territory made by renowned naturalist I. Morris. Data concerning the arrival and rapid spread of the Tawny Coster butterfly (*Acraea terpsicore*) in the Top End and Kimberley are presented elsewhere (Braby *et al.* 2014a, b).

Nomenclature for moths follows Nielsen *et al.* (1996), while that for butterflies follows Braby (2010b). The recent systematic review of Australian butterflies (Braby 2010b; 2011b) incorporates taxonomic changes to the fauna, together with changes in gender of species epithets, published since Braby (2000).

The following acronyms refer to repositories where material has been lodged or accessed:

AM	Australian Museum, Sydney
ANIC	Australian National Insect Collection, Canberra
BMNH	The Natural History Museum, London
NMV	Museum Victoria, Melbourne
NTM	Museum and Art Gallery of the Northern Territory, Darwin
NTEIC	Northern Territory Economic Insect Collection, Darwin

Spatial records

Zodiac Moth (*Alcides metaurus*) (Figure 1)

This large and spectacular diurnal moth in the family Uraniidae has not previously been recorded from the Northern Territory. In Queensland, it is well known for its overwintering aggregations and migratory flights (Smithers & Peters 1977; Coleman & Monteith 1981). At Galiwinku, Elcho Island in the Wessel Islands, I. Morris (pers. comm.) recorded *Alcides metaurus* on several occasions between 1971 and 1976, usually during the 'build-up', and in November 1972 he photographed a specimen (Figure 1) feeding at flowers of a tree of the family Myrtaceae. More recently, L. Wilson (pers. comm.) collected a specimen at Drimmie Head, Nhulunbuy on Gove Peninsula, on 27 October 2006; the moth was collected at night (2000 h) as it flew around a bright light at the Alcan refinery.

Day-flying Moth (*Mimeusemia centralis*)

This day-flying moth in the family Noctuidae, subfamily Agaristinae, has not previously been recorded from the Northern Territory. Examination of material in the ANIC indicates that, within Australia, it was known only from Queensland, extending from Cape York Peninsula, through the Wet Tropics, to Yeppoon (E.D. Edwards, pers. comm.). At Lee Point, Casuarina Coastal Reserve (12.3316°S, 130.8944°E), the author observed two males, one of which was collected (voucher specimen: 1♂ MFBC 00028 (ANIC)), at approximately 0800 h on 18 December 2007 in coastal semi-deciduous monsoon vine thicket. The individuals did not fly (except when disturbed), but were at rest low down on foliage, or sometimes tree trunks, with the head and body oriented downwards and wings folded in the tent position over the abdomen.

Day-flying Moth (*Euchromia creusa*) (Figure 2)

This spectacular diurnal moth in the family Arctiidae has not previously been recorded from the Northern Territory. Within Australia, it occurs from the Torres Strait islands (including Murray, Warraber (Sue), Moa (Banks) and Thursday Islands), to Cape Hillsborough near Mackay in coastal central Queensland, where it may be seasonally abundant (Common 1990). I. Morris (pers. comm.) photographed a specimen (Figure 2) perched on a sandstone rock near Oenpelli in central Arnhem Land in December 1993. It was the only individual encountered.

Figures 1, 2. Two species of diurnal moths newly recorded from the Northern Territory: **1.** Zodiac Moth (*Alcides metaurus*) from Elcho Island; **2.** *Euchromia creusa* from central Arnhem Land. (I. Morris)

Orchard Swallowtail (*Papilio aegeus aegeus*)

In northern Australia west of Cape York Peninsula, this large papilionid butterfly has been recorded in the NT from Groote Eylandt (Common & Waterhouse 1981), Marchinbar Island in the Wessel Islands (Dunn & Dunn 1991; Fenner 1991), Gove Peninsula (Dunn & Dunn 1991; Braby 2011a), and in QLD at Doomadgee (Puccetti 1991) and Karumba (Braby 2000), QLD. The larval food plants include *Micromelum minutum* (Rutaceae) on Marchinbar Island (Fenner 1991) and *Citrus* sp. (Rutaceae) at Nhulunbuy (Braby 2011a). The species has also been recorded in the intervening region of Limmen National Park, NT, where N. Collier and the author observed a male at the Nathan River Ranger Station (15.5768°S, 135.4278°E) on 14 May 2009: the specimen was observed flying in a large open area at the station residents' quarters at 1220 h and then again at 1240 h, suggesting that it was patrolling a mate-location site. Dunn & Dunn (1991), and subsequently Braby (2000, 2004), indicated that the species occurs further west at Darwin, the location of which was based on a record by J.T. Moss who collected a male and female at the RAAF base (adjacent to Darwin airport). The specimens, labelled "Darwin, NT, 30 Jan. 1978,

J.T. Moss", are currently in the private collection of J.T. Moss (pers. comm.) who recalls that "My recollections are hazy but there would have been others as well as the voucher pair. They are slightly below average size for normal *P. aegeus*." The record is curious because *P. aegeus* is not known to occur in the northwestern corner of the Top End, and there is no evidence of an extant breeding population persisting in the Darwin area (see also Meyer *et al.* 2006). Presumably the species was accidentally introduced to the suburbs of Darwin in the 1970s following Tropical Cyclone Tracy, but those founders failed to establish.

White Migrant (*Catopsilia pyranthe crokera*)

There are few records of this migratory pierid butterfly from the northern coastal areas of the Top End. Braby (2000) listed the species from Darwin, but Meyer *et al.* (2006) questioned its occurrence in the Darwin area, although they did acknowledge that adults may possibly be encountered during irregular seasonal migrations. Examination of material preserved in the NTM and NTEIC revealed a total of 13 specimens from the Darwin area collected during three periods: between June and August 1975 (3♂), between December 1975 and February 1976 (6♂, 1♀) and in March–April 1979 (2♂, 1♀) (Table 1). In addition to these specimens, S. Keates and the author observed one individual at Darwin High School adjacent to the George Brown Botanic Gardens near Bullocky Point, Darwin (12.4377°S, 130.8337°E), at 1220 h on 17 March 2010. The specimen settled on the ground (lawn) for a few minutes and, whilst settled, the author was able to carefully approach within 1 m, confirm its identity, sex and phenotypic form. The specimen was a male in good condition and comprised the dark form; it was clearly distinguished from the Lemon Migrant (*Catopsilia pomona*) by the pale brown striations on the underside. Subsequently, the author also recorded the species at Dundee Beach (12.7277°S, 130.3564°E) on 19 April 2012. At this location, large numbers of adults (> 30) were recorded flying along edges of rainforest or in more open areas close to the beach during the afternoon (voucher specimens: 1♂ MFBC 00781 (ANIC), 1♀ MFBC 00120 (ANIC), 1♀ NTM I.006278).

No-brand Grass-yellow (*Eurema brigitta australis*)

In Australia, *Eurema brigitta* occurs commonly along the eastern seaboard, but Waterhouse & Lyell (1914), Common & Waterhouse (1981), Dunn & Dunn (1991) and Braby (2000, 2004) all indicated that it also occurs in the Top End, its occurrence being based on published records for Darwin (Waterhouse & Lyell 1914), Pine Creek (Angel 1951) and Daly River (Hutchinson 1978). Meyer *et al.* (2006) did not record the species in the Darwin area and called for further data to confirm its existence in the region. Extensive field investigations during the past decade by D. Bisa, D.C. Franklin and S. Keates (pers. comm.) and the author have failed to detect this species in the Northern Territory, calling into question the validity of previous records.

Table 1. Records of the White Migrant (*Catopsilia pyranthe*) in the Darwin area, NT.

Location	Date	Observer Name	Specimen	Repository and voucher number
Millner, Darwin	7 June 1975	A.J. Dartnall	1♂	NTM I.002642
Smith St, Darwin	28 June 1975	A.J. Dartnall	1♂	NTM I.002640
Vesteys Beach, Darwin	August 1975	J. Elder	1♂	NTM I.002644
NT Museum, Darwin	3 Dec. 1975	J. Elder	2♂	NTM I.005296, NTM I.005297
Esplanade, Darwin	4 Dec. 1975	J. Elder	2♂	NTM I.002637, NTM I.002638
Howard Springs	9 Dec. 1975	A.J. Dartnall	1♂	NTM I.002641
Smith St, Darwin	9 Dec. 1975	A. Hantos	1♂	NTM I.002639
Fannie Bay, Darwin	29 Feb. 1976	A.J. Dartnall	1♀	NTM I.002643
Quarantine Nursery, Berrimah Farm*	28 March 1979	L. Hall / M. Neal	1♂/1♀	NTEIC 174 / NTM I.002748
Forestry Section, Berrimah Farm	19 April 1979	S. Collins	1♂	NTEIC 180
Bullocky Point, Darwin	17 March 2010	M.F. Braby & S. Keates	1♂	observation

* An additional label reads "Ex. Cassia occidentalis"

Waterhouse & Lyell's (1914) published record for 'Port Darwin' was based on F.P. Dodd material, but personal examination of these historic specimens from the Northern Territory in the AM revealed that several catalogued under the name *Eurema brigitta* had been misidentified: a male labelled "P. Darwin, 16.2.09, F.P. Dodd", "KL15635", "G.A. Waterhouse Collection" proved to be the wet-season form of *E. laeta*; and a female labelled "Groote Eylandt, N. Territory, N.B. Tindale | Nov. 1921", "KL15636", "G.A. Waterhouse Collection" is also *E. laeta*. A second female labelled "P. Darwin, 16:2:09, F.P. Dodd", "G.A. Waterhouse Collection", "KL15635" is *E. brigitta*, but the specimen is unusually marked and it may have been mislabelled following Dodd's return to Kuranda after his 10 month visit to Darwin in 1908–1909. The only reliable record of this species in the Northern Territory is a worn female in the ANIC labelled "11.01S 136.45E, Rimbija Is., Wessel Islands, NT, 18 Jan. 1977, E.D. Edwards" (see also Dunn & Dunn 1991).

Purple Beak (*Libythea geoffroyi genia*) (Figure 9)

Although this nymphalid butterfly may be locally abundant in the Kimberley (e.g. Williams *et al.* 2006; Meyer *et al.* 2013), in the Northern Territory it is rare and very poorly known. Available temporal data in the Kimberley (records held in the Department of Land Resource Management's Flora and Fauna invertebrate atlas) suggest the species is seasonal, with adults recorded from January to July but mainly during the late wet and early dry seasons (March–May). When Waterhouse (1938, p. 219) described the taxon *genia* he recorded it from 'Darwin', noting that "Mr. G. Lyell has a small specimen from Darwin, which is no doubt this race." Waterhouse & Lyell (1914) previously listed the species from Darwin (under the name *niceville*i) and this record was probably based on Lyell's specimen. Subsequently, Common and Waterhouse (1981) recorded the subspecies from Rimbija Island, and this location was based on two males in the ANIC, one labelled "11.01S 136.45E, Rimbija Is., Wessel Islands, NT, 18 Jan. 1977, E.D. Edwards" and the second labelled similarly but with date "21 Jan. 1977". The only other occurrence of the species in the Northern Territory is that of Meyer *et al.* (2006) who recorded it at Palmerston near Darwin, the record being based on a single male captured by G. Martin (pers. comm.) in the early 1990s. Hence, the subspecies *genia* was hitherto known in the Northern Territory from a total of four males from only two locations. It is of interest then that the author has discovered extant populations of *L. geoffroyi* (Figure 9) at two new locations. The first of these was at Fish River Station 15 km SE of the homestead (14.2812°S, 130.9864°E) during which five adults were collected (voucher specimens: 1♂ NTM I.006387, 1♂ NTM I.006389, 1♂ MFBC 00792 (ANIC), 1♀ NTM I.006388) on 1–2 May 2012. On both days small numbers of adults were active for brief periods, between 1130–1400 h, flying rapidly around, or perching on outer twigs of, mature trees of *Celtis philippensis* approximately 3–5 m above ground level. A pupal exuvium (Figure 8) was also found on the underside of a leaf of a sapling (ca. 2.5 m high) of *C. philippensis*, not far from the apex of the plant,

Figures 3–9. Purple Beak (*Libythea geoffroyi*) in the Northern Territory: **3.** habitat at Fish River Station showing semi-deciduous monsoon vine thicket on dolostone outcrop; **4.** habitat at Limestone Gorge, Gregory National Park, showing semi-deciduous monsoon vine thicket on limestone karst; **5.** mature trees of the larval food plant *Celtis philippensis* at Fish River Station; **6.** foliage of *C. philippensis*; **7.** fruits of *C. philippensis*; **8.** pupal exuvium on underside of leaf of larval food plant, Fish River Station; **9.** adult male on the larval food plant, Gregory National Park. (M.F. Braby)

the foliage of which had been extensively eaten. The larval food plant grew in abundance in semi-deciduous monsoon vine thicket on an isolated dolostone hill (Figures 3, 5–7) that was surrounded by savannah woodland; the site showed no evidence of fire and many of the *C. philippensis* trees were large and presumably very old. The second location was at Limestone Gorge, Gregory (Judbarra) National Park (16.0477°S, 130.3940°E). Two males in fresh condition were collected by L.J. Aitchison and the author (voucher specimens: 1♂ MFBC 00806 (ANIC), 1♂ MFBC 00807 (ANIC)) at this site, at 1115 h and 1400 h, on 31 March 2013. They were drinking from damp mud along the main walking track within the gorge flanked by steep limestone cliffs and karst formations supporting extensive patches of semi-deciduous monsoon vine thicket dominated by *C. philippensis* (Figure 4).

Plain Tiger (*Danaus chrysippus cratippus*)

This species is very poorly known from Australia. Its taxonomic distinction from *D. petilia* is currently under review (M.F. Braby, G.E. Farias Quipildos, R.I. Vane-Wright and D.J. Lohman, unpubl. data). In the Top End, *Danaus chrysippus cratippus* was previously recorded from Black Point, Cobourg Peninsula (Common & Waterhouse 1981), based on a single male specimen in the ANIC collected on 30 January 1977 by E.D. Edwards. It has also been recorded further east from Thursday Island in the Torres Strait Islands, QLD, based on a single specimen collected on 25 April 1995 (Lambkin 2009). These are the only previous records of *D. chrysippus* from Australia. During field work on Cobourg Peninsula in February–March 2007, a relatively large number of adult Plain Tigers were recorded, with 13 specimens (8♂, 5♀) collected from several sites by D.A. Lane and the author. The adults occurred together with the Lesser Wanderer (*D. petilia*) and the Swamp Tiger (*D. affinis*), but their flight was somewhat faster and more powerful than that of those species. They were much scarcer, with *D. petilia* being approximately three times more abundant than *D. chrysippus*. Most specimens of *D. chrysippus* were recorded in paperbark swampland along the edge of freshwater lagoons. In this habitat, males were noted to establish mate-location sites by perching low down on reeds and dead branches for short periods before dispersing to other sites. A freshly emerged female was collected at 1300 h on 21 February, drying its wings, low down in foliage. An empty pupal exuvium of a *Danaus* sp. was located nearby on the vine *Cynanchum carnosum* (Apocynaceae), which grew abundantly in the habitat, and it may have been the pupa from which the female had emerged. Another female was observed flying close to the ground searching the *C. carnosum* vines at 1155 h on 15 March, but she did not oviposit. The sites at Cobourg Peninsula were revisited by K. Nishida and the author in April 2008, but despite extensive searches there was no evidence of *D. chrysippus* and all the orange-coloured specimens of *Danaus* captured were *D. petilia*.

Monarch (*Danaus plexippus*)

There are few records of *Danaus plexippus* from northwestern and northern central Australia. The species is not known to breed in the Top End, and a record from the Kimberley (Dunn 1980) is possibly unreliable (Braby 2012a). Several recent records from Darwin, Darwin's outskirts and elsewhere in the Top End are therefore of interest and merit comment. The first of these comprises a freshly emerged female that the author collected near the Amphitheatre of the Museum and Art Gallery of the Northern Territory, at Bullocky Point, Darwin, on 2 September 2009 (deposited in NTM). That specimen had almost certainly originated from a release of butterflies as part of a wedding which was held the previous day in the Museum grounds by 'All About Party Hire', who purchased live Monarchs from the company Butterfly Releases Pty Ltd based in Brisbane. The next record was at Holmes Jungle Conservation Park near Darwin where the author observed an adult in fresh condition between 1645 and 1647 h flying in an open recently-slashed grassy area adjacent to Vanderlin Drive on 5 March 2013. The specimen flew with a powerful flight 1–2 m above the ground and it came within a few metres of the author so that it was readily identified by its large size and distinctive dark orange-brown colour pattern. Subsequently, the species was observed in Kakadu National Park sometime during April 2013 by T. Christopherson, and then during May 2013 the author recorded it near Borroloola and near Elliott, NT, as well as at several sites in the Gulf Country of northwestern Queensland not far from the Northern Territory border (Table 2). Most of these sightings comprised single individuals, but at Karumba, QLD, many adults were seen. Perhaps significantly, a single individual was also observed in central Australia in May 2013. J. Archibald informed me that on 19 May 2013 he and S. Richards observed an adult flying westwards at the Palmer River Crossing on the track to Illamurta Springs, Henbury Station, NT (24.5405°S, 132.6658°E). The observation was made at 1230 h on a fine warm breezy day.

The most recent record of *D. plexippus* was on 30 November 2013 when an adult in perfect condition (recently emerged) was collected from a coastal monsoon vine thicket in the Gunn Point area (12.2276°S, 131.0312°E) (c. 30 km NE of Darwin) by D. Bisa and the author (voucher specimen: 1♂ I.008997 (NTM)).

Northern Argus (*Junonia erigone*)

In Australia, this species of butterfly was previously known only from a single female in the ANIC collected from Rimbija Island, Wessel Islands, NT, on 18 January 1977 by E.D. Edwards (Edwards 1977). At Black Point, Cobourg Peninsula (11.1551°S, 132.1439°E), the author sighted a male on 8 February 2007. The individual was observed at close range (within a few metres) at 1200 h for approximately 5 mins, during which time it patrolled (with a gliding flight with wings held at 180°) or perched (with wings widely expanded) on the ground in

Table 2. Records of the Monarch (*Danaus plexippus*) from the Top End and western Gulf Country of the Northern Territory and northwestern Queensland during 2013. Co-ordinates are in decimal degrees and WGS84 datum.

Location	Latitude	Longitude	Date	Observer Name	Comments
Holmes Jungle CP (Vanderlin Dve), NT	12.4027°S	130.9238°E	5 March 2013	M.F. Braby	1 adult observed at 1645 h
near South Alligator Ranger Station, Kakadu NP, NT	12.6830°S	132.4722°E	April 2013	T. Christopherson	1 adult observed
50 km SSE of town Elliott (Stuart Hwy), NT	17.9727°S	133.4321°E	7 May 2013	M.F. Braby	1 adult observed at 1030 h flying slowly in a northerly direction on eastern side of hwy
Mt Isa (Mullan St-Marian St), QLD	20.7259°S	139.5001°E	9 May 2013	M.F. Braby	1 adult observed at 1025 h EST flying slowly in a northerly direction
Karumba, QLD	17.4866°S	140.8376°E	10, 12 May 2013	M.F. Braby	> 20 adults observed in town and at Karumba Point (1♂ MFBC 00808) (ANIC)
Walker Creek, 36 km E of Karumba, QLD	17.4719°S	141.1794°E	13 May 2013	M.F. Braby	1 adult observed during late morning
Burketown, QLD	17.7410°S	139.5471°E	14 May 2013	M.F. Braby	1 adult observed at 0930 h EST feeding on flowers of *Melaleuca* tree
Gregory River crossing, Burketown-Doomadgee Rd, QLD	17.8913°S	139.2862°E	14 May 2013	M.F. Braby	1 adult collected (1♂ NTM I.008711)
Hells Gate Roadhouse, QLD	17.4554°S	138.3560°E	14 May 2013	M.F. Braby	1 adult observed at 1215 h EST
48 km N of Borroloola, NT	15.6301°S	136.3823°E	15 May 2013	M.F. Braby	1 adult observed at 1620 h flying slowly in a north-westerly direction
Gunn Point, NT	12.2276°S	131.0312°E	30 Nov.2013	M.F. Braby & D. Bisa	1 adult collected in coastal monsoon vine thicket (1♂ NTM I.008997)

an open cleared area adjacent to coastal semi-deciduous monsoon vine thicket. The specimen evaded capture and did not return to the site over the next week as evidenced by the author's repeated and thorough searches. The individual was clearly distinguished from similar congeneric species such as the Chocolate Argus (*Junonia hedonia*) and the Meadow Argus (*J. villida*) by the presence of an olive-brown upperside ground colour in the proximal half of the wings, absence of a chocolate-brown ground colour and absence of broad bright orange rings on the upperside. It was smaller in size than *J. hedonia*, but larger than *J. villida*.

Lurcher (*Yoma sabina*)

Within the Northern Territory, the Lurcher butterfly has been recorded from Gove Peninsula (Fenner 1991) and Groote Eylandt (Common & Waterhouse 1981). Dunn & Dunn (1991) and Braby (2000, 2004) indicated that it occurs further west at Darwin, that location being based on an early record by Waterhouse & Lyell (1914). No further specimens or observations of *Yoma sabina* have been made from the Darwin area since that time (Meyer *et al.* 2006), or indeed anywhere from the northwestern corner of the Top End (M.F. Braby, D. Bisa, D.C. Franklin and S. Keates, unpubl. data), casting doubt on whether the species is established in the area. Lack of confirmation for more than 100 years from this area calls into question the reliability of Waterhouse & Lyell's (1914) historic record from Darwin.

White-banded Line-blue (*Nacaduba kurava felsina*)

Waterhouse & Lyell (1914) described this lycaenid as a subspecies based on a series of 8 individuals (3♂, 5♀) reputedly from Darwin. The butterfly appears to have a small geographical range, being restricted to the higher rainfall areas of the northwestern corner of the Top End (Meyer 1996; Braby 2000). Meyer *et al.* (2006) called for further data to confirm its existence in the Darwin area, noting that the species had not been recorded from the area since Waterhouse & Lyell (1914). The nearest known location of the species to the city of Darwin is Bamboo Creek (given as "the Marrakai Road jungle") (Meyer 1996), approximately 60 km SE of Darwin. At Bullocky Point, Darwin (12.4377°S, 130.8337°E), the author collected a series of 10 males (voucher specimens: 1♂ NTM I.006005, 1♂ NTM I.006006, 1♂ MFBC 00683 (ANIC), 1♂ MFBC 00684 (ANIC), 1♂ MFBC 00685 (ANIC), 1♂ MFBC 00686 (ANIC)) in a degraded patch of monsoon forest at the edge of a crest above Mindil Beach between November 2010 and January 2011. They were collected after midday, settled 3–4 m above the ground in a particular light gap in the understorey. When one male was removed, another male would often enter the light gap soon after and usually perch on the same branch as the first male. These observations suggest the males were using the microhabitat as a mate-location site to detect receptive females for mating. Tropical Cyclone Carlos subsequently destroyed the gap in mid February 2011, after which no more adults were encountered despite careful searches. There was no evidence of *Embelia curvinervia* (Myrsinaceae), the known larval food plant for

the White-banded Line-blue (Meyer 1996), growing in the area, but based on the number of adults encountered it was assumed that the species was breeding in the general vicinity.

Samphire Blue (*Theclinesthes sulpitius*)

This common and widespread species of butterfly inhabits coastal areas of northern and eastern Australia, but there are surprisingly few published records from the Northern Territory. Meyer & Wilson (1995) first recorded it from the Top End where they discovered breeding populations in the Darwin area (i.e. Buffalo Creek, Shoal Bay, and Elizabeth River). Bisa (2013) observed it further west at several sites between Maningrida and Milingimbi in July and August 2007 and in August 2009. More recently, D. Bisa and D.C. Franklin collected a pair (voucher specimens: 1♂ NTM I.006020, 1♀ NTM I.006021) from Bing Bong 48 km N of Borroloola in the Gulf of Carpentaria on 6 January 2011. During a recent visit to this site (15.6301°S, 136.3823°E) the author collected a series of specimens (11♂, 2♀) on 16 May 2013 and found the species to be abundant in estuarine saltmarsh habitat dominated by *Tecticornia* spp. (Amaranthaceae).

Glistening Line-blue (*Sahulana scintillata*)

There are few records of this species of butterfly from the Northern Territory (Franklin *et al.* 2007). Waterhouse & Lyell (1914) listed it from Darwin in September. Dunn & Dunn (1991) referred to an historic record (2♀) from this location in the NMV (voucher specimens: 1♀ LEP-8834, 1♀ LEP-8835, both with label data "P Darwin, Sep. [19]08, P.F. Dodd"); these specimens no doubt formed the basis of Waterhouse & Lyell's (1914) record. Meyer *et al.* (2006) recorded the species from Buffalo Creek, Darwin, in June 2003, from the Hunting Reserve 10 km E of the Adelaide River bridge (Arnhem Hwy) in June 1994, and from the Mary River bridge (Arnhem Hwy) in June 1994. Franklin *et al.* (2007) recorded it from Gunn Point in June 2006. It has also been recorded at Darwin River (12.7872°S, 130.9702°E), where a female was netted (and released) on flowers of Turkey Bush (*Calytrix exstipulata*), on 3 July 2010 (D. Bisa and D.C. Franklin, pers. comm.). At Mary River Reserve on the Mary River crossing of the Arnhem Hwy (12.9084°S, 131.6455°E), the author collected a small series (4♂, 6♀) of adults which were feeding during the afternoon on the flowers of *Lophostemon lactifluus* growing in riparian woodland on 1–2 July 2013. Thus, there are six known locations of *Sahulana scintillata* in the Top End, all from the northwestern corner mainly during the mid-dry season (i.e. June–July). During field work in northeastern Arnhem Land, the author recorded this species on the Gove Peninsula at the Koolatong River crossing (Gapuwiyak-Balma Track) (13.1051°S, 135.7263°E) on 10–13 August 2007. A series of five males (voucher specimens: 1♂ NTM I.005247, 1♂ MFBC 00338 (ANIC)) in good condition was collected, and others observed, between 1540–1720 h. All were flying rapidly close to, or perched 5 m above ground level on, the foliage and

dead twigs of *Lophostemon psidioides* and *Acacia leptocarpa* growing in riparian paperbark open woodland.

Plumbago Blue (*Leptotes plinius pseudocassius*)

In a rather obscure note, Burns (1989) recorded this species of butterfly from the Top End in May 1985, stating "*Sintarucus pseudocassius* [sic] … Four female, three male taken near the South Alligator River in the Kakadu NP. Species numerous." This record was subsequently accepted with some reservation by Dunn & Dunn (1991), and was followed by Braby (2000, 2004, 2008). Dunn & Dunn (1991, p. 419) remarked "Surprisingly, there are no other records of this species from near Darwin… It is desirable to have further confirmation of the species presence in the 'Top End' region." Burns' record is the only report of *Leptotes plinius* from the northern half of the Northern Territory, a species which otherwise is very common and widespread in Queensland and New South Wales, particularly in coastal and near-coastal areas. Despite extensive searches in Kakadu National Park and elsewhere (M.F. Braby, D. Bisa, D.C. Franklin and S. Keates, unpubl. data), additional evidence of this species' presence in the Top End has not been forthcoming. Moreover, *Plumbago zeylanica*, the natural larval food plant of *L. plinius* in Queensland, is distributed widely across the Top End where it occurs in pockets of monsoon vine thicket (Liddle *et al.* 1994), usually associated with rocky areas or outcrops (K. Brennan, pers. comm.). The reliability of Burns' records has previously been called into question, with several facts shown to be in error (Braby 1991). J.F. Burns travelled extensively around Australia during May and June 1985 and he may have accidentally mislabelled some of the material whilst on route from northern Queensland to the Northern Territory.

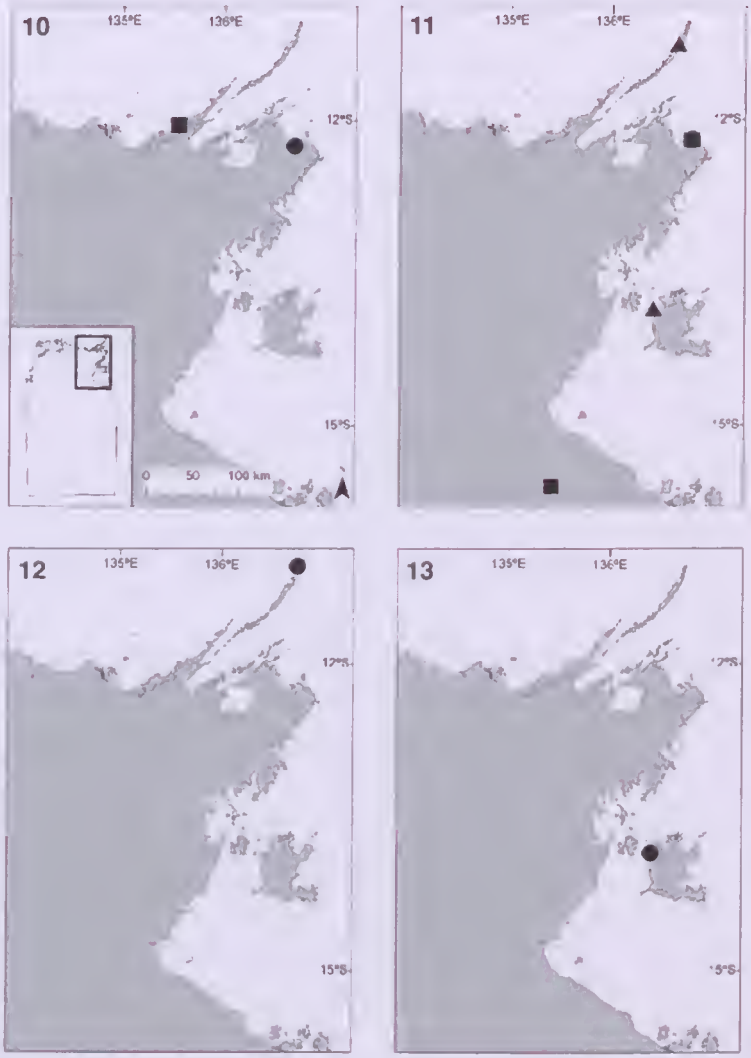
Discussion

The new spatial records documented here, and the review of previous records, serve to clarify the geographical distribution for a number of species of butterflies and diurnal moths in the Top End of the Northern Territory. Of particular interest are the records of the moths *Alcides metaurus*, *Mimeusemia centralis* and *Euchromia creusa*, which represent new occurrences for the Northern Territory. In contrast, the record of the butterfly *Leptotes plinius* is considered to be erroneous and accordingly this species should be removed from the inventory of the Top End's lepidopteran fauna; the only reliable occurrence of this species in the Northern Territory is from central Australia (Pfitzner & Fargher 1976).

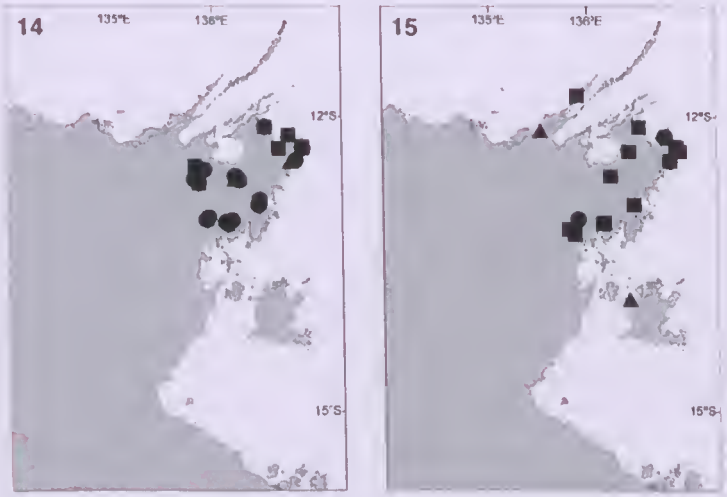
The two locations for *Libythea geoffroyi*, from Fish River Station and Gregory National Park, represent the first confirmed resident breeding populations of the species in the Northern Territory. Johnson & Valentine (1989) described the life history of the subspecies *L. geoffroyi nicevillei* from Cape York Peninsula, QLD, but the larval food plant and early stages of the subspecies *L. geoffroyi genia* from the Kimberley and Top End have not previously been reported. Members of

Libythea specialise on *Celtis* throughout the Old World (Kawahara 2009), and *C. philippensis* is the only species of the genus which occurs in northwestern Australia (i.e. its geographical range overlaps that of *L. geoffroyi genia*). Because of this specific host plant association, it has long been suspected that *C. philippensis* is the larval food plant of *L. geoffroyi genia*. Moreover, adults have frequently been collected in association with this tree (e.g. Williams *et al.* 2006; Meyer *et al.* 2013). The discovery of a pupal exuvium on a leaf of *C. philippensis* and other evidence at Fish River confirms that this tree is indeed the larval food plant of *L. geoffroyi genia*. The two locations at which the butterfly was recorded in the Top End were characterised by semi-deciduous monsoon vine thicket growing on limestone with a high density of *C. philippensis*. This habitat type is very patchy in the inland areas of the Top End; the patches are typically small in extent (comprising a few hectares) and surrounded by an extensive matrix of savannah woodland.

Danaus plexippus does not naturally occur in northwestern and northern central Australia (i.e. the species is non-resident in these regions), and at least one of the records from Darwin originated from a 'butterfly release' from stock reared interstate. Butterfly releases in Australia have largely been founded on this species (New 2008), which is native to North America but which has become naturalised in Australia. The most numerous events at which butterflies are released are weddings, but other social gatherings such as anniversaries, birthdays and even funerals can be the occasion for mass releases. The perceived advantages of substituting butterflies for confetti, balloons, or doves revolve around their aesthetic appeal and cultural/spiritual significance (e.g. they are symbolic of new life). The ecological impacts of introducing species within and outside their natural range are not well understood. New (2008) argued that the educational benefits and enhanced awareness of butterflies in the natural world generated by releases outweigh current conservation concerns, especially for species that are released within their migratory/non-permanent resident range. He recommended that releases ought to be reported/monitored and this is clearly relevant in cases where a species is released well outside its known range because it affects the way in which spatial data are collected and analysed. However, other records from remote areas elsewhere in the Top End, central Australia and the western Gulf Country–where Monarchs were particularly abundant during the early dry season of 2013–most likely represent a large-scale range expansion that occurred during April–May of that year. For three of the observations, adults were flying in a northerly or north-westerly direction, which suggests they may have originated from breeding sites further southeast along the eastern coast (Smithers 1977). Further observations are needed to determine if such a movement is an annual phenomenon or if it was a response to an unusual weather pattern (e.g. the floods that lead to proliferation of larval food resources and hence high butterfly population densities) that prevailed during the 2012–2013 wet season.



Figures 10–13. Known spatial distribution of butterfly and diurnal moth species restricted to northeastern Arnhem Land and/or the Gulf of Carpentaria within the Top End, NT: **10.** Zodiac Moth (*Alcides metaurus*); **11.** Orchard Swallowtail (*Papilio aegeus*); **12.** No-brand Grass-yellow (*Eurema brigitta*); **13.** Red-banded Jezebel (*Delias mysis mysis*). Inset map for Figure 10 shows the Northern Territory. Symbols refer to the following sources of data: ● vouchered specimens in museum collections, ■ field observations, ▲ records published in the scientific literature.



Figures 14, 15. Known spatial distribution of butterfly species restricted to northeastern Arnhem Land within the Top End, NT: (14) Gove Crow (*Euploea alcathoe enastri*); (15) Lurcher (*Yoma sabina*). Symbols refer to the following sources of data: ● vouchered specimens in museum collections, ■ field observations, ▲ records published in the scientific literature.

It is likely that *Danaus chrysippus* is not permanently established on the Australian mainland or Torres Strait, it being a rare immigrant from the Lesser Sunda Islands or Maluku. The presence of numerous adults on Cobourg Peninsula, including a freshly emerged female during the 2006–2007 wet season, provides circumstantial evidence that the species colonised the mainland (i.e. population bred temporarily) during the 2006–2007 wet season, but it did not establish. Similarly, the few records of *Junonia erigone* in January–February suggest this species is a rare vagrant to Australia, with adults dispersing from Indonesia or East Timor during the wet season, possibly facilitated by the monsoon trade winds, which blow in an east-southeasterly direction from the Lesser Sunda Islands.

Collectively, the records for *Catopsilia pyranthe* from the Darwin area and nearby locations suggest that this species is a rare seasonal immigrant or migrant to the northern coastal parts of the Top End, the species being more abundant in the semi-arid areas of the monsoon tropics. Available data suggests migrations are likely to occur mainly during the wet season (anytime from December to April), with occasional appearances in the mid-dry season (June to August).

Clarification of the spatial distribution of several species of butterfly, namely *Papilio aegeus*, *Eurema brigitta* and *Yoma sabina*, in the Top End provides a new perspective on the extent of range restricted taxa in north-eastern Arnhem Land and the Gulf of Carpentaria. Assuming that the early published records of these three species from Darwin and nearby areas are erroneous, their geographical ranges should be considered to be restricted to northeastern Arnhem Land and/or the Gulf of Carpentaria (Figures 11, 12, 15). At least six species in the Northern Territory are confined or almost confined to this region (Figures 10–15), emphasising the uniqueness of the Gove Peninsula and its adjacent islands. Three of these species, *Papilio aegeus* (Figure 11), *Euploea alcathoe enastri* (Braby 2010a) (Figure 14) and *Yoma sabina* (Figure 15), are resident with permanent breeding populations. In contrast, the three other species, the diurnal moth *Alcides metaurus* (Figure 10) the pierid *E. brigitta* (Figure 12) and the Red-banded Jezebel (*Delias mysis mysis*) (Figure 13), appear to be non-resident and are probably vagrants that occasionally disperse from Cape York Peninsula, QLD, across the Gulf of Carpentaria to northeastern Arnhem Land. The larval food plants of *A. metaurus* in northeastern Queensland include three species of *Omphalea* and two species of *Endospermum*, all tropical rainforest vines or tall trees in the Euphorbiaceae (Coleman & Monteith 1981; Monteith & Wood 1987; Harrison 2010; Moss 2010). None of these species occurs on the Gove Peninsula, and only one (*Endospermum myrmecophilum*) occurs in the Northern Territory (Short *et al.* 2011), where it is restricted to the Tiwi Islands and northwestern corner of the Top End (Liddle *et al.* 1994). Therefore, the occurrence of *A. metaurus* in northeastern Arnhem Land in October and November is most likely the result of vagrants dispersing from northern Queensland associated with large-scale movement of adults at that time of year. It remains to be established if *E. brigitta* is permanently established in the Wessel Islands or if the single individual captured by E.D. Edwards was a vagrant; the presence of only a single female specimen in worn condition favours the latter hypothesis. *Delias mysis mysis* is also known only from a single male specimen collected from Groote Eylandt in the Gulf of Carpentaria (Talbot 1928–37, 1943; Braby 2012b). The specimen either represents a vagrant from northern Queensland or it has been mislabelled, in which case the locality is in error.

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Northern Territory Naturalist (2014) 25: 50–63 Research Article

A review of the diet of flower wasps (Hymenoptera: Thynnidae: Thynninae)

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Abstract

The feeding preferences of Australian flower wasps (Thynnidae: Thynninae) are reviewed based on the available literature, a search of a specimen database of almost 8,000 records and an examination of selected representatives of all described genera for the presence of pollen. The vast majority of records of feeding by flower wasps are on nectar, but they also feed on the exudates of scale insects, leafhoppers and aphids. The plants visited most frequently are from the family Myrtaceae, with most other families represented by only a small number of records. Interestingly, there are almost no records from several of Australia's most diverse plant families. It remains to be tested if members of the Myrtaceae show specific adaptations to pollination by flower wasps or if there is variation in wasp morphology in response to variation in diet. Future dietary studies of flower wasps should aim to quantify both floral and other food sources to aid in understanding the ecological requirements of these wasps and how they co-exist in such diverse communities.

Introduction

The name 'flower wasp' was first used by Froggatt (1907) in his book *Australian Insects* and it subsequently came into common usage for the entire Australian thynnine wasp fauna (Tillyard 1926; Naumann 1993). Froggatt applied this common name to the family Thynnidae as it was then constituted. Since that time there have been several taxonomic changes to the higher classification of the group (Pate 1947; Brothers 1975; Brothers & Carpenter 1993) such that the Thynnidae of Froggatt is now a subfamily within a wider interpretation of the family Thynnidae (Pilgrim *et al.* 2008). Within the Australian context, the only other change since Froggatt (1907) was the inclusion into the family of the so-called Blue Ant (*Diamma bicolor*). This distinctive species from southeastern Australia was placed at the rank of a subfamily (Diamminae) by Salter (1963), and is still the only member of that subfamily.

Flower wasps vary in size from 3–45 mm in length. They exhibit a pronounced sexual dimorphism. Males are most commonly predominantly black, though they are often brightly patterned, especially with yellow. While the males are strong fliers, with large species capable of flying several hundred metres (Menz *et al.* 2013), females are always smaller, wingless, and somewhat ant-like in appearance. Females are mostly dull orange to black in colour although some, especially the larger species, are marked with yellow. In Australia, there are approximately 600 described species of flower wasps in 48 genera with an estimated 2,000 species currently represented in collections, including many new genera.

Despite representing a diverse component of the Australian wasp fauna, very little is known about the biology of flower wasps. Courtship is initiated by the female releasing pheromones that rapidly attract males (Alcock & Gwynne 1987; Peakall 1990; Peakall *et al.* 2010). Copulation takes place in flight, with the female curled back underneath the abdomen of the male (Alcock & Gwynne 1987). Because female flower wasps are flightless, they are dependent on the male for food during these courtship flights. Provision of food may be by regurgitation and/or by being flown to a food source *in copula*, with the female then allowed to feed while mating continues (Froggatt 1907; Given 1953). Coupling can last up to two days in captivity (Williams 1919). This prolonged coupling and the pronounced sexual dimorphism is unique and distinctive within the Australian wasp fauna, making mating pairs of thynnines easy to recognise. After mating has been completed, the female is dropped on the ground, after which it parasitises subterranean scarab larvae (Williams 1919; Given 1953; Ridsdill Smith 1970a), although other hosts such as ants (Turner 1914; G. Brown, unpubl.) and bees (Rayment 1935) have also been suggested.

Adult males and copulating pairs are commonly observed at flowers feeding on nectar, with an apparent preference for some genera of the family Myrtaceae (Given 1953; Phillips *et al.* 2009). However, large numbers of individuals have also been observed feeding on *Xanthorrhoea* (Xanthorrheaceae) and *Hakea* (Proteaceae), particularly in southwestern Australia (Phillips *et al.* 2009). Thus far, most knowledge of their food plant preferences comes from opportunistic collections rather than systematic studies. A notable exception to these field records is the work of Menz *et al.* (2013), where pollen swabs were used to show that two species of *Zaspilothynnus* appear to feed primarily on Myrtaceae. Even more poorly documented than nectar foraging, is foraging on exudates of insects, for which there is almost no specific documentation of the flower wasp, or insect, or plant species involved.

While the natural history of most flower wasps remains poorly known, there is increasing interest in their biology due to their role as pollinators of some species of terrestrial orchids. These orchids, of which over 200 species are known from Australia, deceive flower wasps into mating with them. Sexually deceptive orchids engage in chemical and physical mimicry of the calling female, with pollination achieved as the male attempts pre-mating or copulatory behaviour with the flower

(Peakall 1990). As a by-product of mimicking the specific sex pheromones of insects, these orchids have highly specialised pollination systems, typically relying on just a single pollinator species. This reliance on a single pollinator may be a major contributor to the trend of greater rarity in sexually deceptive orchids (Phillips *et al.* 2011), thus highlighting the importance of understanding the ecological requirements of pollinators for plant conservation.

Given the increasing recognition of both the diversity of flower wasps and their role as pollinators, it is pertinent to synthesise current knowledge on their diet. We review the known literature on food plants, use collection details from a nationwide database of specimens and examine museum specimens for the presence of pollen. Combining these approaches represents the first step in understanding the dietary breadth of flower wasps, in investigating if there are generic differences in food plants, and testing if there is an association between diet and mouthpart morphology. This paper is intended as an introduction to further studies on the relationship between flower wasp abundance, their dietary requirements and their effectiveness as pollinators of orchids that attract pollinators through sexual deceit.

Materials and Methods

A search was made for records of flower wasps feeding on flowers and other foods. It involved a literature search including all original species descriptions, an examination of representative specimens from all Australian genera for the presence of pollen, and a search of a personal (GRB) research database containing nearly 8,000 records.

It was assumed that all references to host plants on data labels referred to the flowers unless specified otherwise. The only exception was the genus *Acacia*, which has extra-floral nectaries at the base of the leaves rather than nectar-rich flowers (Bernhardt 1987). For all discussions, we have only gone to the level of plant and wasp genus, as there is currently insufficient data to draw trends at the species level.

Pinned male specimens were examined for the presence of pollen, plus its abundance and distribution, for a comparison of wasp genera. Females were not examined as they were collected *in copula*, walking on the ground or attracting males with pheromones. It is likely that such females had recently emerged from below the ground. As females spend most of their time below the surface seeking hosts to parasitise, it is likely that any pollen present would soon be abraded away. Data were not quantified other than to record whether pollen could be found on representative wasps of all described genera. Observations were based on specimens available in Darwin in August 2013, whether in local collections or on loan from other institutions at that time (Australian Museum, Sydney; Museum of Victoria, Melbourne; Queensland Museum, Brisbane; South Australian Museum, Adelaide; Western Australian Museum, Perth). No attempt was made to identify pollen grains.

Results

Literature Survey

Most published host records of the food plants of flower wasps are for myrtaceous flowers (Tillyard 1926). Within the Myrtaceae, flower wasps have been recorded feeding on flowers of the genera *Eucalyptus* (Burrell 1935; Salter, 1967; Ridsdill Smith 1970b; Alcock 1981; Phillips *et al.* 2009; Menz *et al.* 2013), *Leptospermum* (Bridwell 1917; Burrell 1935; Given 1953; Ridsdill Smith 1970b; Alcock 1981; Alcock & Gwynne 1987; Phillips *et al.* 2009), *Angophora* (Bridwell 1917; Salter 1967), *Melaleuca* (Burrell 1935), *Chamelaucium* (Alcock & Gwynne 1987; Phillips *et al.* 2009) and *Agonis* (Menz *et al.* 2013). Most of these genera produce nectar-rich flowers (Goodacre 1947). Outside the Myrtaceae, large aggregations of feeding flower wasps have been observed on the flowers of *Hakea* (Proteaceae) (Given 1953; Phillips *et al.* 2009) and *Xanthorrhoea* (Xanthorrhoeaceae) (Phillips *et al.* 2009).

Campbell & Brown (1998) intensively sampled flower wasps and other parasites of scarab larvae at two locations on the Northern Tablelands of New South Wales. Almost all observations of feeding were made from myrtaceous flowers of the genera *Baeckea* and *Leptospermum*. *Kunzea* was unattractive, while *Eucalyptus* did not flower during the study due to a prolonged drought.

During a study of the pollination biology of several species of *Acacia* from southeastern Australia, Bernhardt (1987) observed members of the flower wasp genera *Lophocheilus*, *Phymatothynnus*, *Rhagigaster* and *Tachynomyia* feeding on extra-floral nectaries and the nectarless flowers.

Burrell (1935) gave several food plant records for individual wasp genera: *Thynnus* from *Leptospermum* and *Eucalyptus*; *Dimorphothynnus*, *Catocheilus* and *Lophocheilus* from *Eucalyptus*; and *Eirone*, *Neozeleboria*, *Rhagigaster*, *Thynnoides* and *Zeleboria* on the exudates of scale insects (Coccoidea). While thynnines have been observed feeding on the exudates of scale insects (Burrell 1935; Given 1953; Schiestl 2004), leafhoppers (Ridsdill Smith 1970b) and aphids (Given 1953), there are comparatively few records of this behaviour.

Of particular interest is an insightful paper by Given (1957), in which he speculates on different feeding habits, including regurgitation, in relation to modifications to the head shape and mouthparts. This possibility is further discussed by Ridsdill Smith (1970a, 1970b). It should be noted however, that neither author gives quantitative data, making it possible to overestimate the importance of regurgitation without studying this in the broader context of individual feeding strategies.

Additional general observations are given by Illingworth (1921), Given (1953, 1957), Ridsdill-Smith (1970b, 1971), Campbell & Brown (1994) and Brown *et al.*, (1997).

Data labels/Database

Using specimen label data from Australian museums, we compiled records of 39 wasp genera visiting 33 plant genera, representing 14 families (i.e. 121 wasp by plant genus records). Of these, 77 (64%) are from Myrtaceae from 14 genera (Table 1). However, it should be noted that only a small number of specimens examined have host records or collecting methods included on their data labels. The plant genera on which the greatest range of wasp genera have been recorded feeding are *Eucalyptus* (20 genera of flower wasps), *Leptospermum* (9 genera), *Melaleuca* (9 genera) and *Chamelaucium* (9 genera). Of the genera outside the Myrtaceae, the highest numbers of records are from *Hakea* (Proteaceae), with almost all of these from species with cream-coloured flowers from Western Australia. The authors have observed previously that thynnines may be abundant on the flowers of *Bursaria* (Pittosporaceae), *Vigna* (Fabaceae) (grown as legume crops), and *Xanthorrhoea* (Xanthorrhoeaceae).

Table 1. Records of food plants (at the level of genus) for genera of flower wasps based on label data for specimens in Australian museum collections.

FLOWER FAMILY	FLOWER GENUS	WASP GENUS
Amaranthaceae	*Rhagodia*	*Agriomyia*
Amaranthaceae	*Rhagodia*	*Aspidothynnus*
Fabaceae	*Vigna*	*Epactiothynnus*
Fabaceae	*Vigna*	*Umbothynnus*
Goodeniaceae	*Scaevola*	*Acanthothynnus*
Goodeniaceae	*Scaevola*	*Agriomyia*
Goodeniaceae	*Scaevola*	*Zeleboria*
Gyrostemonaceae	*Codonocarpus*	*Encopothynnus*
Lamiaceae	*Pityrodia*	*Guerinius*
Lamiaceae	*Prostanthera*	*Lestricothynnus*
Myrtaceae	*Agonis*	*Zaspilothynnus*
Myrtaceae	*Angophora*	*Aspidothynnus*
Myrtaceae	*Angophora*	*Doratithynnus*
Myrtaceae	*Astartea*	*Elidothynnus*
Myrtaceae	*Astartea*	*Thynnoides*
Myrtaceae	*Astartea*	*Zaspilothynnus*
Myrtaceae	*Baekea*	*Elidothynnus*
Myrtaceae	*Callistemon*	*Tachynomyia*
Myrtaceae	*Chamelaucium*	*Aulacothynnus*
Myrtaceae	*Chamelaucium*	*Catocheilus*
Myrtaceae	*Chamelaucium*	*Macrothynnus*
Myrtaceae	*Chamelaucium*	*Megalothynnus*
Myrtaceae	*Chamelaucium*	*Rhagigaster*
Myrtaceae	*Chamelaucium*	*Zaspilothynnus*
Myrtaceae	*Chamelaucium*	*Zeleboria*
Myrtaceae	*Corymbia*	*Agriomyia*
Myrtaceae	*Corymbia*	*Zaspilothynnus*

(continued)

Table 1. Continued.

FLOWER FAMILY	FLOWER GENUS	WASP GENUS
Myrtaceae	*Eucalyptus*	*Agriomyia*
Myrtaceae	*Eucalyptus*	*Arthrothynnus*
Myrtaceae	*Eucalyptus*	*Aspidothynnus*
Myrtaceae	*Eucalyptus*	*Aulacothynnus*
Myrtaceae	*Eucalyptus*	*Beithynnus*
Myrtaceae	*Eucalyptus*	*Caetrathynnus*
Myrtaceae	*Eucalyptus*	*Campylothynnus*
Myrtaceae	*Eucalyptus*	*Catocheilus*
Myrtaceae	*Eucalyptus*	*Curvothynnus*
Myrtaceae	*Eucalyptus*	*Doratithynnus*
Myrtaceae	*Eucalyptus*	*Elidothynnus*
Myrtaceae	*Eucalyptus*	*Encopothynnus*
Myrtaceae	*Eucalyptus*	*Guerinius*
Myrtaceae	*Eucalyptus*	*Iswaroides*
Myrtaceae	*Eucalyptus*	*Procerothynnus*
Myrtaceae	*Eucalyptus*	*Rhagigaster*
Myrtaceae	*Eucalyptus*	*Rhytidothynnus*
Myrtaceae	*Eucalyptus*	*Thynnoides*
Myrtaceae	*Eucalyptus*	*Zaspilothynnus*
Myrtaceae	*Eucalyptus*	*Zeleboria*
Myrtaceae	*Kunzea*	*Catocheilus*
Myrtaceae	*Leptospermum*	*Arthrothynnus*
Myrtaceae	*Leptospermum*	*Aspidothynnus*
Myrtaceae	*Leptospermum*	*Campylothynnus*
Myrtaceae	*Leptospermum*	*Dimorphorphothynnus*
Myrtaceae	*Leptospermum*	*Doratithynnus*
Myrtaceae	*Leptospermum*	*Eirone*
Myrtaceae	*Leptospermum*	*Elidothynnus*
Myrtaceae	*Leptospermum*	*Lestricothynnus*
Myrtaceae	*Leptospermum*	*Lophocheilus*
Myrtaceae	*Leptospermum*	*Megalothynnus*
Myrtaceae	*Leptospermum*	*Neozeleboria*
Myrtaceae	*Leptospermum*	*Oncorhinothynnus*
Myrtaceae	*Leptospermum*	*Phymatothynnus*
Myrtaceae	*Leptospermum*	*Rhytidothynnus*
Myrtaceae	*Leptospermum*	*Rhytidothynnus*
Myrtaccae	*Leptospermum*	*Thynnoides*
Myrtaceae	*Leptospermum*	*Tmesothynnus*
Myrtaceae	*Leptospermum*	*Zaspilothynnus*
Myrtaceae	*Leptospermum*	*Zeleboria*
Myrtaceae	*Melaleuca*	*Agriomyia*
Myrtaceae	*Melaleuca*	*Aspidothynnus*
Myrtaceae	*Melaleuca*	*Doratithynnus*

(continued)

Table 1. Continued.

FLOWER FAMILY	FLOWER GENUS	WASP GENUS
Myrtaceae	*Melaleuca*	*Elidothynnus*
Myrtaceae	*Melaleuca*	*Guerinius*
Myrtaceae	*Melaleuca*	*Iswaroides*
Myrtaceae	*Melaleuca*	*Macrothynnus*
Myrtaceae	*Melaleuca*	*Procerothynnus*
Myrtaceae	*Melaleuca*	*Rhagigaster*
Myrtaceae	unidentified	*Psammothynnus*
Myrtaceae	*Scholtzia*	*Guerinius*
Myrtaceae	*Scholtzia*	*Lophocheilus*
Myrtaceae	*Scholtzia*	*Rhagigaster*
Myrtaceae	*Scholtzia*	*Zaspilothynnus*
Myrtaceae	*Verticordia*	*Belothynnus*
Myrtaceae	*Verticordia*	*Catocheilus*
Myrtaceae	*Verticordia*	*Oncorbinothynnus*
Myrtaceae	*Verticordia*	*Zaspilothynnus*
Orchidaceae	*Prasophyllum*	*Dimorphorphothynnus*
Orchidaceae	*Prasophyllum*	*Eirone*
Orchidaceae	*Prasophyllum*	*Rhagigaster*
Orchidaceae	*Prasophyllum*	*Rhytidothynnus*
Orchidaceae	*Prasophyllum*	*Zaspilothynnus*
Pittosporaceae	*Bursaria*	*Agriomyia*
Pittosporaceae	*Bursaria*	*Arthrothynnus*
Pittosporaceae	*Bursaria*	*Guerinius*
Proteaceae	*Adenanthos*	*Elidothynnus*
Proteaceae	*Banksia*	*Catocheilus*
Proteaceae	*Hakea*	*Aspidothynnus*
Proteaceae	*Hakea*	*Campylothynnus*
Proteaceae	*Hakea*	*Catocheilus*
Proteaceae	*Hakea*	*Dimorphorphothynnus*
Proteaceae	*Hakea*	*Doratithynnus*
Proteaceae	*Hakea*	*Macrothynnus*
Proteaceae	*Hakea*	*Rhagigaster*
Proteaceae	*Hakea*	*Thynnoides*
Proteaceae	*Hakea*	*Zaspilothynnus*
Proteaceae	*Lambertia*	*Aspidothynnus*
Sapindaceae	*Alectryon* (as *Heterodendrum*)	*Encopothynnus*
Sapindaceae	*Atalaya*	*Aspidothynnus*
Sapindaceae	*Atalaya*	*Doratithynnus*
Scrophulariaceae	*Eremophila*	*Aspidothynnus*
Scrophulariaceae	*Eremophila*	*Dimorphorphothynnus*
Thymelaeaceae	*Pimelea*	*Agriomyia*
Thymelaeaceae	*Pimelea*	*Guerinius*
Thymelaeaceae	*Thryptomene*	*Aspidothynnus*

(continued)

Table 1. Continued.

FLOWER FAMILY	FLOWER GENUS	WASP GENUS
Xanthorrhoeaceae	*Xanthorrhoea*	*Catocheilus*
Xanthorrhoeaceae	*Xanthorrhoea*	*Doratithynnus*
Xanthorrhoeaceae	*Xanthorrhoea*	*Macrothynnus*
Xanthorrhoeaceae	*Xanthorrhoea*	*Zaspilothynnus*

All wasp genera for which there were more than five host genera records (i.e. *Agriomyia, Aspidothynnus, Catocheilus, Elidothynnus, Guerinius, Rhagigaster, Rhytidothynnus, Thynnoides* and *Zaspilothynnus*) have been found on several families of plants including the Myrtaceae. All genera with host records had at least one record from the Myrtaceae except for two: *Acanthothynnus* with one record from *Scaevola* (Goodeniaceae) and *Umbothynnus* with one record (but multiple specimens) on *Vigna* (Fabaceae). Both genera are small and poorly represented in collections.

Of the non-flower records, five wasp genera (i.e. *Aspidothynnus, Doratithynnus, Encopothynnus, Isnaroides* and *Rhytidothynnus*) were recorded from *Acacia* (Fabaceae), where they were most likely feeding on extra-floral nectaries rather than flowers. There were also records of *Neozeleboria* trapped in the sticky seeds of *Pisonia brunoniana* (Nyctaginaceae) and *Eirone* feeding on exudates of the soft scales *Eriococcus coriaceus* (Coccidae).

There were no host label data records for the wasp genera *Aeolothynnus, Ariphron, Bifidothynnus, Chilothynnus, Dythynnus, Gymnothynnus, Leiothynnus, Nitidothynnus, Pentazeleboria, Tachynoides, Tachyphron* or *Thynnus* on the specimens examined.

Examination of specimens

Pollen was found on many specimens and most genera. While some individuals had a dense covering of pollen, most had only a few grains that were retained in depressions or grooves (but not punctures) particularly at the base of the antennae, the anterior transverse groove on the pronotum and at the base of the wings (but not in cavities in the fore coxae). Those specimens that had a heavy pollen load did have some pollen on the setae. Wasps frequently preen themselves and such specimens were probably caught on flowers before they had time to remove much of the pollen.

Pollen was usually found on the integument, but not attached to the setae themselves (Figures 1, 2), although the setae may help to hold some grains in place. All setae arise from punctures in the integument so that the densities of the setae and the punctures are identical. However, puncture size and setal length do not seem to be related to each other or the ability of a species to retain pollen. Whether these factors contributed to a wasp's ability to accumulate pollen was not considered here.

Although poorly represented in collections, pairs that had remained *in copula* after collection had little pollen attached to their bodies. Those that were examined also had some pollen on the top of second abdominal segment (metasomal tergite 1), although this may be coincidental. Given that mating pairs feed extensively on nectar, it seems likely that the paucity of pollen grains is an artefact of the pinning process.

Representative specimens of all the genera listed in Table 1 had pollen on the body, as did most of the remaining genera: *Aeolothynnus, Ariphron, Chilothynnus, Gymnothynnus, Leiothynnus, Nitidothynnus, Pentazeleboria, Tachynoides, Tachyphron* and *Thynnus*. Several genera had little pollen. Those genera with a concave head (i.e. *Tachynomyia,*

Figure 1. Mating pair of flower wasps *Zaspilothynnus nigripes* at inflorescence of *Hakea trifurcata* (Proteaceae) with the winged male (above) covered in pollen and feeding the female by regurgitating nectar. North of Badgingarra, southern Western Australia. (Keith Smith)

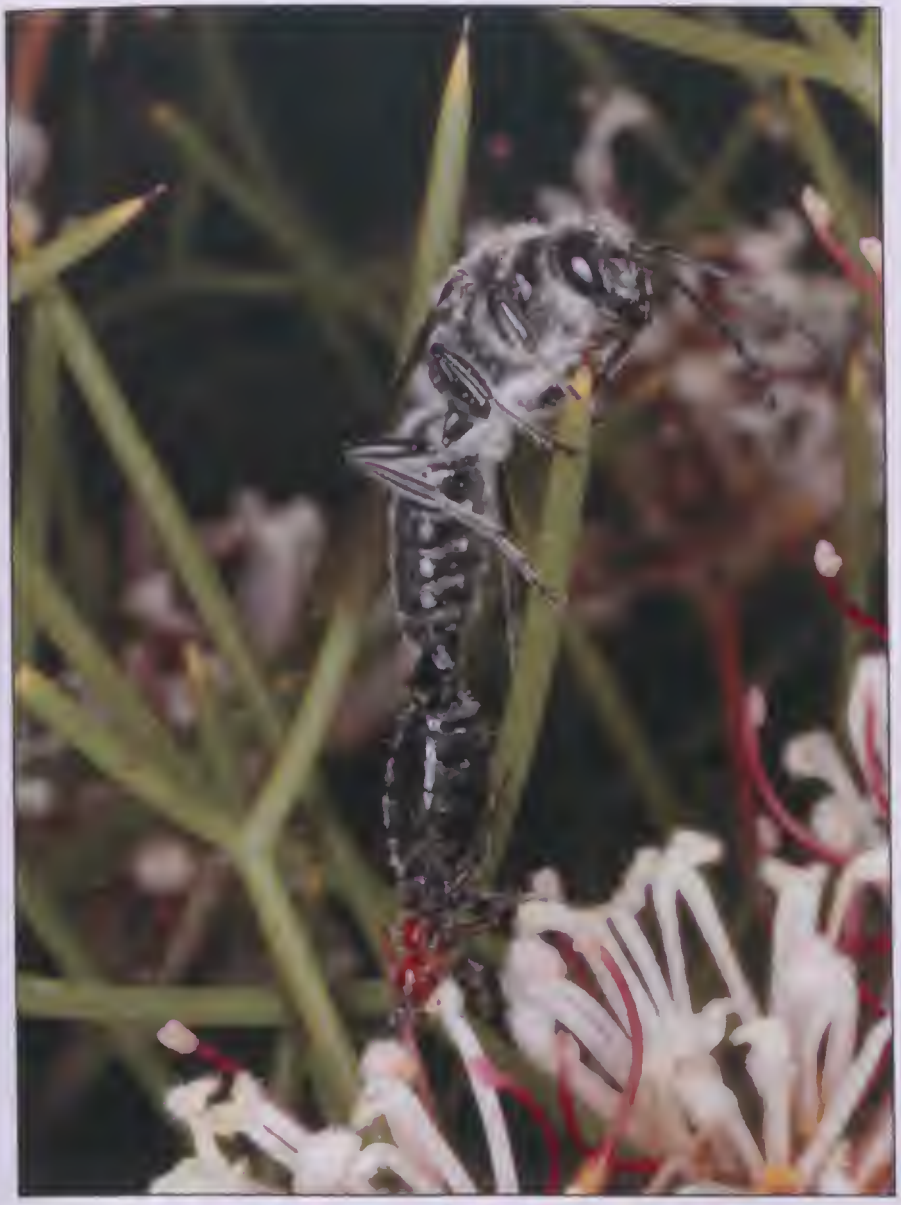

Figure 2. Same mating pair of *Zaspilothynnus nigripes* as shown in Figure 1 with the wingless female (below) feeding on nectar. North of Badgingarra, southern Western Australia. (Keith Smith)

Tachynoides and *Tachyphron*) tended to have very little pollen, most of which was behind the top of the head and on the front of the thorax. *Gymnothynnus*, which has a strongly punctate head and thorax, tended to have dirt rather than pollen on the body; and *Nitidothynnus*, which has a smooth head and body, had no pollen. This may be an indication that a smooth body does not retain pollen for any length of time. No pollen was found on *Bifidothynnus* or *Dythynnus*, but most specimens of *Dythynnus* had an unknown white residue on their bodies.

Discussion

Despite the prominence of flower wasps in the Australian wasp fauna, and the abundance of specimens in museums collections, there are relatively few host plants documented. This introductory paper confirms that flower wasps are found on Myrtaceae more often than other families, but that they also utilise other plant families. Notably, several diverse groups in the Australian flora have been rarely or never recorded as food plants (e.g. Asteraceae, Ericaceae). Most records are from Myrtaceae that typically have open-faced flowers that permit easy access to nectar. Outside the Myrtaceae, the only plant genus where a wide range of genera has been recorded is *Hakea* (Proteaceae). Several species of *Hakea*, such as *H. trifurcata*, often attract large numbers of mating pairs (Phillips *et al.* 2009). In southwestern Australia, some genera of flower wasps are commonly seen on *Xanthorrhoea* (Phillips *et al.* 2009). Outside of these groups, records of thynnines foraging on nectar or pollen are relatively infrequent. However, systematic collection of pollinators is required to more accurately determine the extent to which this trend occurs due to a bias in collecting, arising from geographical and taxonomic variation in collection effort.

The prevalence of thynnines as floral visitors to some plant genera, in particular *Chamelaucium*, *Leptospermum* and *Hakea*, raises the possibility that some plant species may have undergone adaptations towards pollination by flower wasps. Increasing the attractiveness of a plant to flower wasps is most likely to take the form of a floral structure that increases their foraging efficiency, or tailoring the nectar reward to the preference of thynnines (e.g. Shuttleworth & Johnson 2009). An understanding of floral adaptations to pollination by flower wasps may aid in understanding why these wasps appear to show strong preferences towards certain plant genera.

Interestingly, some abundant genera of flower wasps, such as *Neozeleboria* and *Phymatothynnus*, are relatively rarely observed foraging on nectar. Similarly, in some habitats in southern Australia that support a high density of these wasps, it is very rare to see them foraging on nectar. These observations raise the possibility that in some genera, and in some environments, flower wasps might switch from using nectar plants to other food sources such as the exudates of other insects. These possibilities need to be evaluated by combining pollen swabbing (e.g. Menz *et al.* 2013) with detailed observations of the behaviour of pollinators.

Morphology of the pollinators in relation to diet

The morphology of the male may he relevant to how often flower wasps feed. In males of *Tachynomyia, Tachyphron* and *Tachynoides* (and also the New Guinean genera *Deuterothynnus* and *Heligmothynnus*) the head is strongly concave posteriorly and margined with long setae. This concavity is capable of retaining a large volume of liquid (presumably nectar which, when retained in preserved pinned specimens, dries to a small, pale mass). This liquid was found by Given (1953) to be used by male *Tachynomyia* to feed a female during courtship and coupling. Whether this is the only use is unknown. This structure may enable these genera to collect nectar faster by capillary action and may act as a food reserve so that wasps visit flowers less often and move longer distances between food plants or between breeding and feeding sites (e.g. Ridsdill Smith 1970b).

Interestingly, different species of male flower wasps show considerable variation in the shape and size of their mouthparts. The mouthparts tend to be longer in those species that have an enlarged clypeus, which may represent a specialisation for smaller wasps to use deeper flowers. While in many members of the Myrtaceae the nectar is presented on the relatively open-faced flower, it would be of interest to test if there is an association between mouthpart morphologies and those species that frequently feed on tubular flowered species.

The absence of pollen on the limited number of known specimens of *Bifidothynnus* may be a reflection of the small sample size, but this genus is so distinct morphologically (most obviously in the male genitalia and wing venation and the female terminalia) from all other flower wasps that there may be corresponding differences in its biology that are yet to be observed. Similarly, *Dythynnus* lacked pollen on the body of all specimens examined. Most individuals did however, have traces of an unidentified white residue. This may be remnants of hemipteran exudates or other non-floral food.

Conclusions and future directions

While this study has supported the conclusion that members of the Myrtaceae tend to be the main food plants of flower wasps, it also highlights how little is known about other food sources. In this context, studies of alternative food sources will be important for not only understanding the ecological requirements of pollinators and their susceptibility to landscape modification, but also for resolving how such diverse communities of thynnines co-exist with apparently similar diets. Resolving these issues will require systematic studies of the diet and behaviour of flower wasps. Such work will be important for not only understanding the biology of a diverse group of insects, but understanding their role in the pollination of a large number of Australian plant species.

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Changes in dominance of dipteran families on Coral Sea cays over ten years during a period of substantial vegetation change

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Abstract

The habitat on the Coringa-Herald group of coral cays within the northern Coral Sea underwent profound change after about 2000 because of extensive dieback of the dominant forest trees. This work summarises surveys on these cays in 1995, 1996, 1997 and 2007, in order to understand the effect on the native insect fauna of the introduced biological control agent, the non-specific predatory ladybird beetle *Cryptolaemus montrouzieri* (Coleoptera: Coccinellidae), that was liberated to control scale insects (Hemiptera: Coccidae) whose infestation was responsible for the dieback of the forest trees. This paper documents the families of Diptera (flies) collected on the surveys and it records changes in presence and abundance of Chloropidae, Phoridae, Sarcophagidae, Canacidae, Lonchaeidae and Chironomidae sampled in pitfall traps and yellow pans. Despite some differences in collecting methods and seasons between surveys, there is evidence of substantial changes in the presence and relative abundance of these families. The decline of several families on Coringa Cay and on North East Herald Cay between 1995/96 and 2007 could be the result of a trophic cascade of species loss following tree dieback. One of the most conspicuous changes was that Chloropidae increased on North East Herald Cay between 1997 and 2007 following increases in populations of scale insects, but chloropids are not thought to have had a direct role in the control of scale insects.

Introduction

The Coringa-Herald group of coral cays is located 450 km east of Cairns in the northern Coral Sea (Figure 1). They are part of the Coral Sea Conservation Zone, are a National Nature Reserve, and are protected as an IUCN Nature Reserve because of their importance as nesting grounds for endangered sea birds and turtles. Seventeen of the 27 bird species recorded from the Coral Sea Conservation Zone are

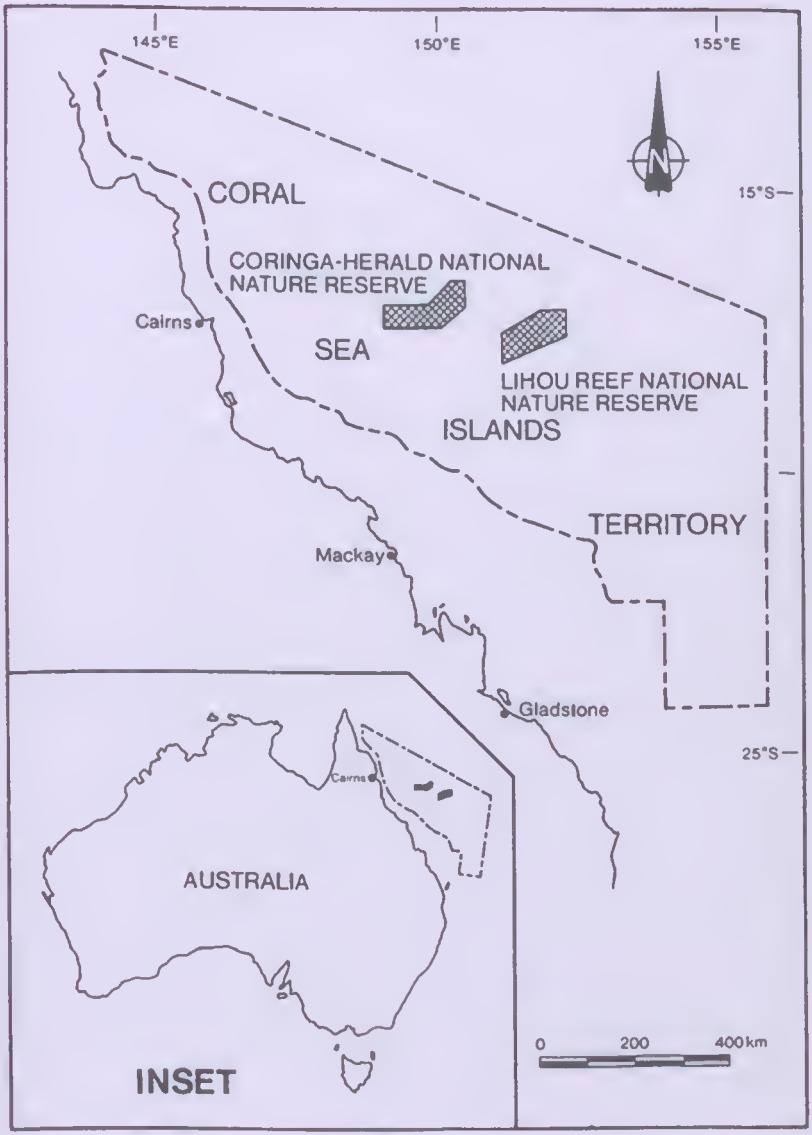

Figure 1. Map of the Coral Sea Islands Territory showing the location of the Coringa-Herald National Nature Reserve.

listed under the Japan/Australia Migratory Birds Agreement and the China/Australia Migratory Birds Agreement. This means that Australia has an obligation to protect the nesting sites of the listed migratory and endangered bird species on those cays. Their nesting sites are in the trees on these cays and beneath them on the ground. Several species of bird, notably Black Noddies (*Anous minutus*) and Mutton Birds (*Puffinus pacificus*), depend for nesting on *Pisonia grandis* trees, originally present on three cays – North East Herald, Coringa and Magdalene (Handler *et al.* 2007, Greenslade 2008, Hoffman & Kay 2008, Hill *et al.* 2003). In 2001, the *Pisonia* trees suffered extensive dieback on North East Herald Cay and they had nearly disappeared on Coringa Cay due to the impact of the sap-feeding scale insect *Pulvinaria urbicola* (Hemiptera: Coccidae) (Figure 2). An ant-scale mutualism that facilitated the multiplication of the scale was suggested as the main factor involved in the dieback (Smith *et al.* 2004). The Australian Department of the Environment, Water, Heritage and the Arts decided to introduce the non-specific predatory ladybird *Cryptolaemus montrouzieri* (Coleoptera: Coccinellidae) to control the scale insect and thus reduce *Pisonia* dieback and in doing so reduce the numbers of 'tramp ants'. This term relates to species of ant that have spread, and are still dispersing from their original location usually into tropical areas, mediated by human movements. They tend to be pest species, not only for economic but also social reasons.

The impacts on the insect faunas as a result of the invasions by the tramp ants as well as the release of the ladybird beetle were unknown because the faunal composition on the cays prior to these events had not been comprehensively sampled or the data analysed and presented. As a first step, Greenslade (2007) summarised unpublished results of three invertebrate surveys carried out opportunistically in 1995, 1996 and 1997 before the onset of the *Pisonia* dieback and the rise of the tramp ants. Subsequently, in 2007 the second author and Roger Farrow undertook a survey for invertebrates on all four cays within the Coringa-Herald group and summarised the results from all the surveys (Greenslade & Farrow 2008).

Greenslade & Farrow (2008) found that the cays supported a diverse insect fauna, and that between 1995 and 2007 some species of the families Formicidae (ants) and Coccidae (scale insects) showed significant increases in overall numbers suggesting that an ant-scale mutualism was indeed responsible for the abundance of the scale and the consequent dieback of its *Pisonia* host (Greenslade & Farrow 2008, Greenslade 2010). At the same time, an overall decline in species richness and abundance of other insect species was recorded on the cays before the dieback (Greenslade 2008, 2010), although not all taxa from these surveys were able to be identified and counted to family level (Greenslade & Farrow 2008). One key group, not identified by these authors beyond the level of order, was Diptera (flies). As this group was abundant and species-rich in the collections, it was considered valuable to identify dipteran families and count individuals in each family, along with establishing

the timelines of their population shifts. This analysis was done to test the hypothesis that changes in populations of the dipteran families were correlated with *Pisonia* dieback, with the main aim being to provide additional information on the effects of *Pisonia* dieback and tramp ant invasion on the assemblages of native insects on these isolated coral cays. Furthermore, because of the difficulty of access to these cays and the limited opportunities to collect insects there, a record of the Diptera present at different times over this 12 year period is a useful baseline for future environmental surveys.

Adult Diptera from all the surveys had been sorted to order prior to the analysis reported here. A superficial examination of these collections indicated that the abundance and dominance of species caught in both the pitfall traps and the yellow pans had changed between 1997 and 2007 (Greenslade & Farrow 2008).

Figure 2. Photograph showing the habitat on North East Herald Cay in May 2007. Note dead *Pisonia grandis* trees that had previously formed the canopy and understorey of recently established, opportunistic *Abutilon indicum* shrubs exploiting the light gaps created by the death of the *Pisonia* trees. (Penelope Greenslade)

That initial sorting was carried out by the second author and the specimens were subsequently allocated to family by the first author at The Australian Museum under the guidance of the third author. This paper reports on the identification and relative abundance of selected dipteran families to provide a possible explanation of the observed changes over time including consideration of the influence, if any, of the *Pisonia* dieback and tramp ant presence.

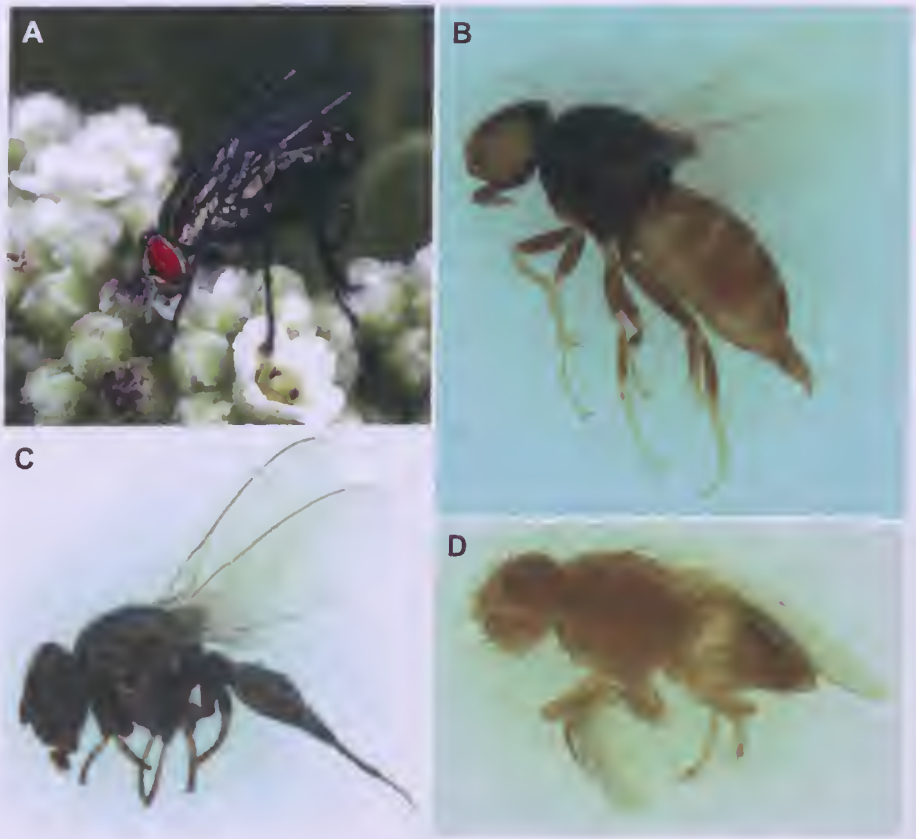

Figure 3. Representative species of Diptera dominating samples from North East Herald Cay: **A.** Sarcophagidae, here shown feeding on flowers of Octopus Bush (*Argusia argentea*) (Chris Freebairn); **B.** Chloropidae (John Martin); **C.** Lonchaeidae (John Martin); **D.** Canacidae (John Martin).

The mean temperatures at the Coringa-Herald group are similar between March and May, with March being at the end of the wet season and May the start of the dry season. The mean diurnal temperature range and rainfall for March from 1981–2010 was 25.6–29.7 °C and 214.2 mm, respectively (BOM 2011 for Willis Island). The mean temperature range and rainfall for May from 1981–2010 was 24.2–27.8 °C and 91.8 mm, respectively (BOM 2011). This group of cays experiences a cyclone roughly every 20 years. In 1989 Tropical Cyclone Airvu caused extensive damage, but the evidence of this cyclone was not obvious at the time of the 2007 survey. Cyclone Yasi also caused extensive damage when it struck in 2011, but since no invertebrate monitoring had been undertaken since 2007, the effects are unknown.

Methods

The Diptera came from the following four surveys (see Table 1), each being described in greater detail by Greenslade & Farrow (2008). The 1995 and 1996 surveys were conducted in March and consisted of various trapping methods on North East Herald Cay and Coringa Cay over approximately one month. The 1997 survey was conducted in May and consisted of various trapping methods on North East Herald Cay over a period of approximately one week. Samples identified from pitfall and yellow pan catches are summed for all methods and dates within each year. The 2007 survey was conducted in May over four days and consisted of various trapping methods on North East Herald Cay and South West Herald Cay, but pitfall traps were only deployed for two days on Magdalene and Coringa Cays. The pitfalls and yellow pans used were identical to those used in the 1997 survey, so the numbers of insects per trap day were strictly comparable.

Dichotomous keys from the *Manual of Nearctic Diptera* (McAlpine 1981, 1987) and *Insects of Australia* (CSIRO 1991) were used to identify adult Diptera specimens, which had been stored in 70% ethanol. All the specimens resulting from these surveys are deposited in the Australian Museum in Sydney.

Data analysis

All dipteran specimens from the 1995, 1996, 1997 and 2007 surveys were identified to family (Table 1). The data shown in that table are the number of individuals in each family for each collection event. For this summary the 1995 data were amalgamated with the 1996 data because of the small number of specimens collected in 1996, and the fact that the collections were made by the same group of researchers at the same time of year. No statistical tests were performed because the variation in collection methods, timing and duration between the surveys resulted in incomparable data sets, and the number of traps from which the flies were taken was not recorded in the 1995 and 1996 surveys.

Table 1. Numbers of Diptera in each family collected from four Coral Sea Islands in years from 1995 to 2007. Percentages are given in brackets after the absolute number of individuals. Only values of 1% or more given.

Family	North East Herald			South West Herald			Coringa			Magdaleine		
DATES	1995/6	1997	2007	1995/6	1997	2007	1995/6	1997	2007	1995/6	1997	2007
Sarcophagidae	2	2	316(78)						8			
Lonchaeidae	60(14)	3	1			1	504(47)					1
Chloropidae	18(4)	2	35(9)			14	14(1)					
Canacidae	162(38)	0	18(4)			4	429(41)					
Phoridae	28(6)	0	30(7)			1	21(2)					
Mycetophilidae	6(1)	0	0				54(5)					
Ephydridae	45(10)	0	0				2					
Muscidae	0	0	0				4					
Calliphoridae	3	2	2				1					
Pipunculidae	1	1	2			6	1					
Lauxaniidae	43(10)	0	0				23(2)					
Cecidomyiidae	2	0	3			2	3			1		
Hippoboscidae	2	2	0				1					
Dolichopodidae	1	0	0									
Stratiomyidae	23(5)	0	0				14(1)					
Chironomidae	35(8)	0	0				2					
Ceratipogonidae	1	0	0									
Total individuals	**432**	**12**	**407**	**0**	**0**	**28**	**1073**	**0**	**8**	**1**	**0**	**1**
Total families	**16**	**6**	**8**	**0**	**0**	**6**	**14**	**0**	**1**	**1**	**0**	**1**

Results

The survey data, at least from North East Herald Cay and also to a more limited extent from the other three cays, allows the relative abundance of dipteran families between years and families to be reported here with confidence as to their reliability and relevance to other biotic changes that took place over the 10 year period between the survey years.

North East Herald Cay families

The total number of dipteran families found on North East Herald Cay over all years was 16. This number is quite small considering that there are nearly 100 families of Diptera in Australia (CSIRO 1991). In 1997 representatives of six families were collected on North East Herald Cay, and in 2007 eight families recorded (Table 1). The composition by family and number of individuals also differed; three families that were present in 2007 (i.e. Phoridae (commonly known as scuttle flies), Canacidae (beach flies) (Figure 3D) and Cecidomyidae (gall midges)), were not present in 1997, and eight families (i.e. Chironomidae (non-biting midges), Mycetophilidae (fungus gnats), Ephrydidae, (brine flies), Lauxaniidae, Hippoboscidae (louse flies), Dolichopodidae (longlegged flies), Stratiomyidae (soldier flies) and Ceratopoconidae (sand flies)) were present in 1995/96, but absent in 2007 (Table 1).

Dominance on North East Herald Cay in 1995, 1997 and 2007

The numerically dominant families in terms of relative abundance on North East Herald Cay were different in each of the sampling periods (Table 1). In 1995/96 Canacidae were dominant comprising 38% of individuals caught, with the next most dominant family being Lonchaeidae (lance flies) (Figure 3C) with 14% individuals (Table 1). In 2007 Sarcophagidae (flesh flies) (Figure 3A) were dominant with 77% of the dipteran population (Table 1).

Coringa Cay 1995/96 and 2007

On Coringa Cay in 1995/96 the most abundant families caught were Lonchaeidae at 47% and Canacidae at 40%, with various other families comprising the remaining 13 % (Table 1). In 2007 only Sarcophagidae were collected, but only eight individuals from this family were trapped (Table 1). As these flies may have been attracted to the preservative in the traps, drawing wider inferences on the Coringa Cay dipteran population in 2007 is not possible.

Discussion

Large shifts in the populations of flies are considered as useful baseline data which provide direction for future research on the environment of these ecologically important coral cays. Although the composition of the dipteran populations did change in synchrony with the dieback of the dominant trees, differences

in collection sites, methods, and seasons between collections in 1995/96 and the two later surveys means that the hypothesis that population shifts of Diptera actually correlate with tree dieback cannot be tested statistically. Nonetheless, some changes are obvious in some families. For instance, the abundance of Loncheidae on North East Herald Cay was high in 95/96, but low in later years. And it appeared that the dominant dipteran families did change in parallel with *Pisonia* tree dieback, release of the biological control agent, and increases in populations of scale insects and tramp ants on North East Herald Cay and Coringa Cay, but whether these latter factors are directly related to fly abundance is unlikely. Another factor that would influence the samples is migration to and from the cays (Farrow 1984). As the dipteran families recorded here are not known to be specialised for long distance migration, the most likely climatic event that would permit them to disperse to the cays are cyclones.

North East Herald Cay

In 2007 members of the family Sarcophagidae were the dominant flies in traps with 77% of total abundance (Table 1). Greenslade & Farrow (2008) noted that an adult sea turtle carcass was present on the cay at that time. The turtle had become trapped in a coastal shrub and died. A species of hide beetle, *Dermestes ater* (Coleoptera: Cleridae), inhabited the turtle carcass, and fly larvae were found in an adjacent turtle egg clutch (Greenslade & Farrow 2008). Sarcophagid larvae live and breed in freshly decomposing flesh (CSIRO 1991), and the succession of insects on carcasses usually begins with larval Diptera before progressing to Coleoptera as decay progresses (Amendt *et al.* 2004). The relative dominance of Coleoptera in the carcass in 2007 is probably evidence of the age of the carcass with the adult sarcophagids already having emerged. Turtle strandings are assumed to occur rarely on small coral cays, and therefore, the high number of adult sarcophagids recorded in 2007 is most likely because of this serendipitous bounty. As such, it is unlikely that the change in numbers of sarcophagids from 1997 is related to *Pisonia* dieback.

Excluding sarcophagids, three other families of flies assume co-dominance in terms of abundance – Chloropidae (38%), Phoridae (32%) and Canacidae (20%) – together making up 90% of the fauna (Table 1). The 2007 data show four major differences from the earlier collections (Table 1). The most dominant family in 1995/96, Chironomidae (midges), was absent in 2007 (Table 1). Chloropidae (frit flies) (Figure 3B) showed an approximately 2.8-fold increase in dominance from 1997 to become the most dominant family in 2007 (Table 1). Phoridae (scuttle or hump-backed flies), which were absent in 1997 but present in 1995/96, appeared in the 2007 collection as the second most dominant family at 32 % (Table 1). Alternatively, Lonchaeidae showed a 14-fold decrease to become the least dominant family in 2007 (Table 1). Canacidae (shore flies) increased in relative representation in 2007 from 1997, but were abundant in 1995/96. This difference may be related to a change in resources along the shoreline for this family.

Absence of Chironomidae in 2007

Chironomidae are aquatic insects, and one subfamily, Clunioninae, inhabits intertidal marine environments (Ferrar 1987). Thus the chironomid life cycle is independent of tree habitats and associated animals, and its absence from the 2007 collection is not likely to be a result of ecological shift as a result of *Pisonia* dieback. It is more likely that collections were undertaken during a time when chironomids were absent as adults. Larval stages of chironomids can last from a few days to more than a year and the emergence of adults is largely dependent on weather and lunar cycles (Ferrar 1987; Macintosh *et al.* 2008). The survey on North East Herald Cay in 1995/96 was over a longer period than the 2007 survey, so that timing or seasonal migration may have been the reason why this family was absent from collections in 2007.

Increase of Chloropidae in 2007

Chloropidae have a wide range of larval habits. The chloropids encountered on South West Herald Cay are members of the subfamily Oscinellinae, several members of which are known to prey on scale insects (Ferrar 1987). Numbers of scale insects were approximately 50-fold fewer in 1997 and earlier than in 2007 (Smith & Papecek 2001a, Smith & Papecek 2001b), which coincides with the changes in relative abundance of chloropids (Table 1). However, chloropids were also found in relatively high numbers on South West Herald Cay, where *Pisonia* trees are now completely absent (Batianoff *et al.* 2010). There were at least three different chloropid species present in the collections so, whilst it is possible that the particular species on North East Herald Cay might be parasitising scale insects, the unidentified species on South West Herald Cay might not. Furthermore, because chloropids were present prior to the scale outbreak, there is no clear indication that those on North East Herald Cay played a major role in controlling numbers of scale insects. Their role in control of the scale insects is further brought into question because of the rapid decline of the scale insects in 2002, directly after the introduction of the biological control agent (Smith & Papecek 2001a, Smith & Papecek 2001b). Identification of all chloropids to species level would improve our understanding of invertebrate-invertebrate interactions on these cays. In particular, such information would add to the comprehensiveness of any assessment pertaining to the ladybird beetle release and effectiveness.

Appearance of Phoridae in 2007

A few species of Phoridae are known to parasitise species of the beetle family Coccinellidae and others are associated with ants (Ferrar 1987). Although phorids were present in 1995/96, they were absent in 1997 despite a moderate ant population (Table 1) (Greenslade & Farrow 2008). The North East Herald Cay Phoridae have been identified more precisely and they include one specimen of the genus *Dohrniphora* which could not be identified to species level as it was a female. The other specimens (nearly 100 individuals from North East Herald Cay and Coringa Cay)

all belong to *Megaselia spiracularis*, a new record for Australia (Disney & Greenslade 2012), so there would have been no interaction of phorids with the introduced ladybird *Cryptolaemus montrouzieri* or with the dominant and recently invading ant species *Tetramorium bicarinatum*. As *M. spiracularis* is saprophagous, its appearance in 2007 is possibly associated with the turtle carcass on North East Herald Cay.

Decline of Lonchaeidae

Members of the Lonchaeidae are most often secondary invaders of fruit after other insects have already laid their eggs or after mechanical damage to the fruit has occurred. As a result they can initiate decay (Ferrar 1987). However, the larvae of many species have also been found in association with wood boring Coleoptera, where they live in galleries excavated by the beetles and feed on dead beetle larvae (Ferrar 1987). Because *Pisonia grandis* is one of the only two fruit-bearing woody trees on North East Herald Cay (Batianoff *et al.* 2010), it is possible that the lonchaeids were dependent on either *Pisonia* fruit or on an association with wood-boring Coleoptera found in rotting timber. After the dieback in 2001, recruitment of *Pisonia* trees by seedlings was low (Burger 2005) and tree densities had not returned to 1997 levels by 2007. Therefore, the 14-fold lonchaeid population decline (when sarcophagids were omitted) (Table 1) may be due to loss of fruit hosts rather than to wood borers. The latter would be expected to increase with the death of trees. Further identification and future surveys would help explain the role of loncheids on these cays, and improve our understanding of trophic cascades when a single plant species is lost from an ecosystem.

Data from Coringa Cay can also be used to support the hypothesis that declines in the lonchaeid populations were the result of dieback. In 1995/96, when *Pisonia* trees were still present on Coringa Cay, the Lonchaeidae was the most dominant family (Table 1). In 2007, after the *Pisonia* trees had died and so had been absent from this cay for six years (Greenslade 2010), the Lonchaeidae were absent from collections (Table 1). Whilst the 1995 survey was conducted in the wet season and the 2007 survey was conducted in the dry season and was of short and limited duration, data between wet and dry seasons from North East Herald Cay show no change in lonchaeid dominance (Table 1). This suggests that the seasonal difference between collections is unlikely to have had an effect on lonchaeid populations. *Pisonia* dieback was therefore likely to be the cause of lonchaeid population declines on both North East Herald Cay and Coringa Cay.

Conclusions

Of the six families of flies to have notable population changes in synchrony with the invasion of the invasive tramp ants, *Pisonia* dieback, and deliberate release of the predatory ladybird beetle, four (i.e. Sarcophadidae, Phoridae, Canacidae and Chironomidae) are thought not to have any correlation with any of these events. In particular, the populations of Phoridae and Sarcophagidae are almost certainly

related to the death of a sea turtle on North East Herald Cay as well as to the possible presence of other avian corpses. There is no indication that the introduction of the ladybird beetle affected fly populations, although the effect of the invasive ant *Tetramorium bicarinatum* on fly larvae is unknown.

The two families of flies that showed large changes in abundance after the dieback of the *Pisonia* trees, and that also have an ecological relationship with the terrestrial vegetation, were Chloropidae and Lonchaeidae. The population increases of chloropids on North East Herald Cay between 1997 and 2007 can be associated with increases in the population of scale insects. However, these flies are not thought to have a significant role in control of scale insects because they were present before the scale outbreak, and notable scale decreases occurred after the release of a predatory beetle that feeds on the scale insects. There were at least two species of chloropid in the collections leaving ambiguities with respect to the role of certain chloropids at specific times and on different cays. To be comprehensive in the assessment of the effects of the ladybird beetle on both the scale population and native fauna, all the chloropid species should be examined and identified. The relative population changes of Lonchaeidae could be an indicator of the loss of fruiting trees as well as of the invasive ant abundance (Greenslade 2008); the latter caused a trophic cascade of species loss following *Pisonia grandis* dieback and *Cordia subcordata* defoliation. As the relative abundance of Lonchaeidae changed in synchrony with *Pisonia* dieback, two scenarios are suggested – either these lonchaeids are dependent on *Pisonia* fruit, or that the loss of the *Pisonia* trees caused a trophic cascade of species loss on Coringa Cay.

Due to the incomparable data sets, the conclusions drawn here are mostly speculative. However, as baseline data, the data provided here provide a starting point for future research in the conservation of these globally important environments.

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