REVIEW OF THE BIOLOGY AND DISTRIBUTION OF NEWMAN FRUIT FLY, *DACUS NEWMANI* (PERKINS) (DIPTERA: TEPHRITIDAE), A CRYPTIC DACINAE SPECIES FROM THE DRY INLAND OF AUSTRALIA

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Summary

Dacus newmani is a commonly collected native fruit fly in Australia. However, *D. newmani* is poorly understood but has no economic impact on commercial fruit industries. *Dacus newmani* is trapped in large numbers in dry environments, unlike many other fruit flies. Trade partners may become concerned by these large numbers and may need to be assured that this species does not pose a threat to exports. This review aims to provide information to allay any concerns. There is very little information on hosts including native hosts, although a member of Asclepiadaceae (the native *Marsdenia australis*) is speculated to be a host. As no hosts are known, there is also no knowledge about immature forms. There is only one description of female flies. Adult males are possibly long lived with up to two generations per year but generally seem to be single brooded. *Dacus newmani* adult males are attracted to cuelure but not to wet food lures. The fly is distributed mainly through arid areas in Australia in all mainland states. It is not known in any other countries. *Dacus newmani* remains a cryptic species despite being known of for decades.

Key words: non-economic, hosts,

INTRODUCTION

Dacinae fruit flies (Diptera: Tephritidae: Dacinae) are one of the key pest groups in Asia and the Pacific regions. Larval stages feed on a broad range of fruit and vegetables causing direct damage, fruit drop and loss of export markets (Clarke *et al*. 2005; Hancock *et al*. 2000)). Initial research focused on the main economic fruit flies such as Mediterranean fruit fly *Ceratitis capitata* (Weidemann), an introduced species now restricted to Western Australia (Dominiak and Mapson 2017). Queensland fruit fly *Bactrocera tryoni* (Froggatt) is a native pest originally infesting native hosts but was reported infesting commercial fruit in the late 1890's. *Bactrocera tryoni* is the most destructive fruit fly in eastern Australia (Dominiak and Daniels 2012). Some other native fruit flies have extended their host range into a range of commercial fruits such as *B. neohumeralis* (Hardy), *B. jarvisi* (Tryon) and *B. cucumis* (French 1907) but are restricted to several states only (Dominiak and Worsley 2016, 2017, 2018).

There are several native fruit flies which are not known to have bred in commercial fruit. These include *Dacus absonifacies* (May) and *D. aequalis* (Coquillet) where little is known about their habitat or hosts; they are rarely trapped in large numbers (Gillespie 2003). *Dacus newmani* (Perkins) is another native species that has not been detected in commercial produce. It is commonly called Newman fly but also was known as the inland fruit fly in South Australia (Madge *et al.* 1997) because it is not commonly trapped along coastal areas (Dominiak *et al.* 2011, 2015a). *Dacus newmani* is sometimes called the drought fruit fly because it is trapped in large numbers during droughts. In some periods, there are large numbers of *D. newmani* trapped in larger numbers than *B. tryoni.* particularly in some areas such as the former Fruit Fly Exclusion Zone (Gillespie 2003).

Some trade partners are concerned by the lack of knowledge regarding *D. newmani*. While the males are well known and have been trapped for many decades, there is little information of other life stages and the species remains an enigma. This review seeks to provide all the published knowledge on *D. newmani* in one paper to help dispel those concerns.

SYSTEMATIC RELATIONSHIPS

Dacus newmani is one of six species placed within the Australo-Pacific Dacus group within *Dacus* clade A (Krosch *et al.* 2012). Their analysis may have been directed at more economically important fruit flies, however the evolution of *D. newmani* and other lesser known flies was also identified. The distribution of Dacini extends from Africa, where *Dacus* dominates, across to India, Australia and the Pacific where *Bactrocera* dominates (Drew 2004). The Australo-Pacific *Dacus* diverged about 46 million years ago. *Dacus absonifacies* and *D. aequalis* diverged first followed by *D. newmani* and *D. bellulus* (Drew and Hancock) many millions of years later. Virgilio *et al.* (2009) claimed that *Dacus* clade A appeared to have specialised on the Apocynaceae while *Dacus* clade B specialised on Curcurbitae and Passifloraceae. *Dacus* clade A consists of a mix of taxa from Africa and Australasia and contains several off-shoots during its evolution. One very early off-shoot eventually migrated into the Asian region. A later off-shoot of *Dacus* clade A apparently left Africa at around 55 million years ago, possibly migrating from the north-east of Africa through the current Middle East and eventually becoming the Asia/Australian *Dacus* (Krosch *et al.* 2012).

TAXONOMY

The species was named after Mr Newman, the Government Entomologist of Western Australia, who was the first to collect specimens of the species in 1918. Perkins (1937) claimed it was necessary to create a new genus for "*newmani"* as it was so different from the other Dacinae and closer to African species rather than Australian species. Perkins placed the species in the genus *Neodacus* and was very easily distinguished by the presence of a supernumerary lobe in the wing of the male (Perkins 1937). The species differed from all other Australian Dacinae due to two scutellar bristles, in the absence of the post-sutural lateral yellow stripes and from most species by the presence of prsc. bristles. May (1963) reported that the tergites of six species of Australian Dacinae (viz. *absonifacies*, *aequalis*, *auricoma*, *newmani*, *petioliforma* (May) and *signatifrons*) were fused. Drew (1972) moved the species from *Neodacus* to the subgenus *Dacus*. Some authors refer to the species as *Bactrocera newmani* (Cowley *et al.* 1990) however, most authors use *Dacus newmani*.

Drew (1989) stated that *D. newmani* was similar to *Dacus bellulus* (Drew and Hancock) and *Dacus signatifrons* (May) in possessing a narrow costal band confluent with or just overlapping R_{2+3}. However, *D. newmani* differs from the other species in having facial spots absent, mesopleural stripe reaching midway between anterior margin of notopleural callus and anterior npl. bristle dorsally, mesonotum rich chocolate brown with a central elliptical yellow spot. All three species are attracted to cuelure (Drew 1989).

BIOLOGY

While the biology and distribution is now well understood for economic pests such as *B. tryoni* (Clarke *et al.* 2011), there is little known about *D. newmani*. Here, the published knowledge for *D. newmani* is reviewed. Other sections such as lures, climate and distribution have been more widely reported in published papers.

Egg, larval and pupal stages

Immature stages of *D. newmani* have never been reported. Exley (1955) described larvae from 18 species but none from the group with fused tergites (*D. absonifacies, D. aequalis, D. auricoma, D. newmani, D. petioliforma* and *D. signatifrons*). Drew (1989) described female specimens from Carnarvon dated 1929. This is the only reference describing the adult female. Drew (pers. com. 1992) suggested that *D. newmani* was likely to attack seed pods of a low shrub belonging to Asclepiadaceae. Eggs may be laid into long bean type pods and pupate inside the pods and emerge when pods crack open. If these observations are accurate, adult *D. newmani* should be found in traps during or after pod burst. Drew (1989) stated that it was unlikely that *D. newmani* pupae could survive in soil in hot dry localities. Drew suggested that *D. newmani* probably had a similar behaviour to the allied species *D. aequalis* that pupate within host fruit remaining on the plant.

Adult behaviour

Dacus newmani appears to be single brooded (Gillespie 2003). Female *D. newmani* have not been detected in South Australia (Madge *et al.* 1997) or any other state (other than Western Australia) and there is no understanding of their behaviour. Female fruit flies of most species are frequently attracted to protein lures however there are no reports of female *D. newmani* detected in protein traps (eg Dominiak *et al.* 2003, Dominiak and Nicol 2010). Drew (1989) described female adult specimens from Carnarvon dated September 1929.

LURES AND SURVEILLANCE

Dacus newmani is not attracted to wet food lures (Drew and Hooper 1981) but is attracted to both cuelure and raspberry ketone. The allied species of *D. absonifacies, D. signatifrons* and *D. aquilonis* are also attracted to both lures (Drew and Hooper 1981) but cuelure is normally used in surveillance traps (Drew 1989). Hancock *et al*. (2000) also claimed these species (*D. absonifacies*, *D. newmani*, *D. signatifrons*) were attracted to cuelure. *Dacus petioliforma* is not attracted to male lure (Hancock *et al*. 2000). Gillespie (2003), Osborne *et al.* (1997), Royer and Hancock (2012) found *D. newmani* in cuelure baited Lynfield traps. Using cuelure as the attractant, Cowley *et al.* (1990) reported similar numbers of *Bactrocera newmani* (Perkins) were trapped in Jackson traps and Lynfield traps at Applethorpe in southern Queensland.

Dominiak *et al.* (2011) found *D. newmani* was attracted to cuelure baited Lynfield traps but not attracted to MacPhail traps baited with protein autolysate or orange concentrate. Dominiak *et al.* (2011) claimed that it was not surprising that orange concentrate lure was not attractive as *D. newmani* was not known to infest citrus fruit. They also suggested that *D. newmani* may not need protein in its life cycle as other fruit flies do.

Zingerone attracted 12 species of *Bactrocera* and *Dacus* but no *D. newmani* were detected in northern Queensland (Fay 2012). In a Sydney evaluation, zingerone lures attracted four *D. newmani* compared with no *D. newmani* in cuelure baited Lynfield traps (Dominiak *et al*. 2015a). Dominiak *et al.* (2011) found *D. newmani* were attracted to combination lures using cuelure and methyl eugenol when evaluated in the dry inland at Griffith but not in Sydney. Similarly, *D. aequalis* and *D. absonifacies* were not attracted to the same lure combinations in Sydney (Dominiak *et al.* 2011). No *D. newmani* were trapped in Lynfield traps baited with melolure or cuelure but both lures attracted many *D. aequalis* and *D. absonifacies* (Dominiak *et al.* 2015b).

In north Queensland, Royer (2015) tested ten lures including cuelure, raspberry ketone and similar analogues but no *D. newmani* were detected. *Dacus aequalis* and *D. bellulus* were strongly attracted to cuelure and raspberry ketone and less strongly to zingerone. Conversely *D. absonifacies* was strongly attracted to zingerone and less strongly to cuelure and raspberry ketone.

CLIMATIC INFLUENCES

May (1963) claimed the records suggested that the distribution of *D. newmani* covered areas of Australia where the annual rainfall ranged from 10 to 30 inches (25 to 75 cm) annually. Hancock (2010) claimed that *D. newmani* was widespread in semi-arid regions in Australia west of the Great Dividing Range (excluding Cape York Peninsula). *Dacus newmani* was found in semi-arid areas of north-west, central and eastern Australia (Drew 1989; Royer and Hancock 2012). This contrasts with many other Australian fruit fly species, such as *B. neohumeralis* and *B. tryoni*, that prefer coastal or wetter environments (Yonow and Sutherst 1998; Dominiak and Worsley 2006). *Dacus newmani* is rarely trapped in larger urban areas (*unpub. data*). Larger urban environments have higher humidity than rural areas (Dominiak *et al.* 2016). Nine species were trapped in cuelure baited traps in Sydney but *D. newmani* was not recorded (Dominiak *et al.* 2015b). There were seven species recorded in Sydney traps; there were four *D. newmani* trapped of the 6,740 flies trapped in zingerone baited traps. No *D. newmani* were detected in cuelure traps although 8,309 other flies were trapped (Dominiak *et al.* 2015a).

The flying period for *D. newmani* is mid-summer and its existence to the west of the New South Wales Great Dividing Range, a harsh habitat, is barely tolerated by most other fruit flies (Gillespie 2003). Drew (1989) commented that the species was distinct from other Dacinae as it did not occur in wet coastal areas. There may be a hybrid with *D. bellulus* (Drew and Hancock) between Bundaberg and Cairns; the range of *D. bellulus* is typically Cape York Peninsula, coastal Northern Territory and Torres Strait islands (Hancock 2010).

DISTRIBUTION

Dacus newmani is frequently claimed to be endemic to arid parts of Australia. Hancock *et al.* (2000) claimed *D. newmani* was distributed in semi-arid areas of northern, central and eastern Australia, and in Cairns in northwest Queensland. Osborne *et al.* (1997) also trapped *D. newmani* in semi-arid regions of Australia as expected, and in the wet tropic at Cairns. Its distribution covered parts of all mainland states except Victoria (Hancock 2013). This claim is not consistent with the Australian Plant Pest Database (APPD) (APPD 2015).

The APPD offers some guidance (see below) to distribution however many records lack one or more of the following information critical fields: collector's name, identifier's name and collection date (APPD 2015). Despite these limitations, the APPD information is provided for six states. There were 519 records of *D. newmani.* There were also 184 records of *B. newmani* in the APPD with 144 occurring between 1960 and 1964. It might be assumed that the taxonomy was being re-evaluated in this period. However there are six records in 1977 and seven records of *B. newmani* in 2009. Of the 184 records, 170 records are from South Australia (up to 1984) and 11 records from Northern Territory (up to 2009). There is no obvious reason for the use of *B. newmani*. It is assumed *D. newmani* and *B. newmani* are the same species and nationally distributed.

Northern Territory

May (1963) reported that *D. newmani* was recorded in traps in citrus orchards at Alice Springs. May (1965) claimed only males were detected in large numbers in citrus orchards in Alice Springs from February to October in 1962. A few males were detected at Lee Point and Warrabri. There were 274 records of *D. newmani* and 10 records of *B. newmani* (APPD 2015).

Queensland

Dacus newmani was originally trapped in the Stanthorpe district in 1928. It was subsequently trapped at Lawes, Offham (near Cunnamulla), Stanthorpe and Toowoomba in lure traps but neither the lure or trap was described by May (1953). Royer and Hancock (2012) reported detections from Blackall, Blackwater, Brisbane, Bundaberg, Cairns, Charleville, Charters Towers, Dimbulah, Gladstone, Laidley, Mackay, Mt. Isa and Townsville however it is not clear if these detections were in drier rural environments or urban environments with modified conditions (Dominiak *et al*. 2006). Lloyd *et al.* (2010) reported low numbers of *D. newmani* in the Central Burnett. In the APPD, there were 106 records of *D. newmani* in Queensland (APPD 2015).

New South Wales

The first detections in New South Wales appear to be at Broken Hill and Menindee in western New South Wales in 1962 (May 1963). Gillespie (2003) reported a peak in populations in November. Male *D. newmani* have been trapped in the Fruit Fly Exclusion Zone and Dubbo (Dominiak *et al.* 2003, 2009; Dominiak and Nicol 2010). A search of the NSW fruit fly monitoring database (Dominiak *et al*. 2007) indicates that *D. newmani* is found in the districts of Balranald, Broken Hill, Goolgowi, Griffith, Grong Grong, Hay, Hillston, Leeton, Menindee, Narrandera, and Yanco. The APPD has 11 records of *D. newmani* in NSW (APPD 2015).

Other Australian states

In the APPD (APPD 2015), there are several records for Carnarvon in Western Australia. There were 89 records of *D. newmani* in Western Australia. In Victoria, there were 34 records of *D. newmani* and three records of *B. newmani.* In South Australia, there appears to be a different view in as much as there were five records of *D. newmani* and 170 records of *B. newmani* (APPD 2015). May (1963) reported that *D. newmani* was recorded frequently in the Adelaide hills district in South Australia.

Other countries

Given the apparent preference of *D. newmani* for arid environments, it is not surprising that it has not been detected in the Pacific area. In Papua New Guinea, Fletcher (1998) did not detect any *D. newmani* in cuelure and methyl eugenol baited traps. Tenakanai (1996) did not detect *D.newmani* in Papua New Guinea. Drew and Romig (2001) did not record *D. newmani* from Bougainville in Papua New Guinea. In a current review of PNG Dacinae, over 280 species have been recorded, 25 of which belong to the genus *Dacus*. *Dacus newmani* is not one of the *Dacus* species (Drew, pers comm.). In the subsequent survey, *D. newmani* was not one of the 194 species recorded in Papua New Guinea (Clarke *et al.* 2004).

Regarding other Pacific countries, *D. newmani* is not reported as emerging from fruit from 127 plant species in 95 genera and 52 families, sampled in the Federated States of Micronesia (Leblanc 1997; Leblanc *et al*. 2004). Hollingsworth *et al.* (2003) did not detect *D. newmani* from the over one million fruit flies collected in the Solomon Islands and it was not detected in an earlier survey by Vagalo *et al*. (1997). Drew and Romig (2001) did not record *D. newmani* from the Solomon Islands or Vanuata (Allwood *et al.*1997; Drew and Romig 2001). *Dacus newmani* has not been detected in New Caledonia (Amice and Sales 1997; Norrbom and Hancock 2004) or Indonesia (White and Evenhuis 1999). *Dacus newmani* was not detected in Tonga, Western Samoa, American Samoa, Niue (Heimoana *et al*. 1997), Cook Islands, French Polynesia (Purea *et al*. 1997), Fiji, Tuvalu, Wallis and Futuna, Tokelau or Nauru (Vueti *et al.* 1997).

HOST RANGE

Within Australia, about 90 species of Dacinae are known but only a few of these became pests of introduced fruits (Drew 1989). In relation to native hosts, Perkins (1937) described *D. newmani* from specimens collected in 1918 bred from a native fruit collected at Carnarvon, Western Australia (May 1963). May (1953) recorded that *D. newmani* was reputed to be bred from native fruits but no host records were reported. May (1957) reported that *D. newmani* was not detected in commercial, ornamental or wild hosts while in a later study, Smith *et al*. (1988) claimed the hosts were unknown.

Hancock *et al*. (2000) reviewed the hosts of 269 fruit fly species and may offer a clue to possible hosts of *D. newmani*. There may be indicators to *D. newmani* hosts from the close aligned species. Hancock *et a*l. (2000) reported that no host plants were recorded for *D. newmani* but suggested the host might be a species of Asciepladaceae. This suggestion might be linked to the comment by Hancock *et al.* (2000) that there was one record of *Marsdenia rostrata* (R. Br) in Asclepiadaceae as a host of the close species *D. absonifacies* based on observations by May (1957). *Marsdenia rostrata* is a host for *D. aequalis* also based on observations by May (1957). However, for the other close species, Cucurbitaceae was a host of *D. petioliforma* based on Drew (1989). Hancock *et al*. (2000) report no host for *D. signatifrons* but claimed it was likely to be a species of Asclepiadaceae. The possible hosts of *D. newmani* remains supposition until a host plant is actually found with immature stages of *D. newmani*.

Backyard fruit is generally recognised as high risk fruit because of the lack of care and fruit fly management practiced by urban growers. Any fruit infested with *D. newmani* is therefore likely to be detected in backyard fruit carried by travellers. In an analysis of fruit intercepted in South Australia during a 37 year period, only *B. tryoni* and *C. capitata* were reported as infesting fruit seized from travellers (Maelzer 1990). Produce inspected included apple, apricot, avocado, banana, cumquat, feijoa, fig, grapefruit, guava, lemon, loquats, mandarin, mango, nectarine, orange, peach, pear, persimmon, plum, quince, tomato and watermelon. In an analysis of fruit intercepted at the Victoria and New South Wales border during a seven year period, only *B. tryoni* was reported as infesting fruit seized from travellers (Dominiak *et al*. 2000). Fruits inspected included capsicums, citrus, pome fruit, stone fruit, tropical fruit and tomatoes.

In regard to commercial produce, *D. newmani* was not recorded as a pest infesting any commercial fruit (Madge *et al*. 1997; May 1957). In Western Australia, no *D. newmani* were reported from 82 potential host plants infested by *C. capitata* near Broome (Woods *et al*. 2005). Lloyd *et al*. (2013) sampled over 40,000 citrus fruit and found four species infesting fruit but no *D. newmani* were detected infesting fruit.

Asclepiadaceae host but which one?

Within the Apocynaceae family (Krosch *et al.* 2012), there are five subfamilies, one of which is Asclepiadoideae. *Marsdenia* is a genus within this subfamily (Endress and Bruyns 2000). The possible Asclepiadaceae host remains speculation however some species would seem unlikely. Asclepiadaceae are an Australian group of milk sapped vines and shrubs. The possible host would likely originate from the more likely host species based on the range of the pest and the possible host.

Marsdenia rostrata has distribution primarily along coastal areas along eastern Australia (ALA 2015) and this is more consistent with the distribution of *D. absonifacies* but less consistent with *D. newmani* (Osborne *et al*. 1997). *Dacus aequalis* is distributed mainly around Sydney (Osborne *et al.* 1997) and has a population peak in April-May (Gillespie 2003). *Marsdenia rostrata*, the host for *D. aequalis*, only occurred in rainforest and not suburbia or open sclerophyll forests (Raghu *et al.* 2000) and this casts further doubt on *M. rostrata* as a host for *D. newmani*. Osborne *et al.* (1997) noted that a better understanding of both *D. absonifacies* and *D. aequalis* was limited as information on host fruit was lacking.

However, *D. newmani* is found in drier climates and so *M. rostrata* is an unlikey host. Similarly *Marsdenia suaveolens* (R.Br.), *Marsdenia lloydii* (P.I. Forst.), *Marsdenia liisae* (J.B.Williams), *Marsdenia flavescens* (A.Cunn. ex Hook) and *Marsdenia fraseri* (Benth) occur along the eastern Australian coast (ALA 2015) and are unlikely hosts as *D. newmani* appears to have originated in Western Australia. *Marsdenia pleiiadenia* (F.Muell. P.I.Forst) has some inland distribution but largely has a coastal distribution. *Dacus absonifacies* has two population peaks in September and April and has a coastal range (Gillespie 2003).

Marsdenia australis (R. Br. Druce) has common names including doubah, bush banana and native pear and is distributed across the inland of all Australian mainland states (ALA 2015). This is a woody vine climbing over trees and scrubs. It is found throughout Central Australia and often found close to creek beds. Growth is rapid, responsive to rain and may flower within six weeks. *Marsdenia viridiflora* (R. Br.), also known as native pear, is distributed inland mainly in Northern Territory, New South Wales and Queensland. *Marsdenia australis* flowers mainly from August to November with peak in September (ALA 2015). This is largely consistent with peak detections of *D. newmani* in September. But it is currently unclear if *D. newmani* appears at flowering or fruiting, just by comparing these two databases. *Dacus newmani* may be a pollinator and lay eggs in another host. *Marsdenia viridiflora* has a peak flowering in January and April (ALA 2015). It is possible that *D. newmani* may complete its life cycle in *M. australis* and *M. viridiflora* however further searches for possible hosts could assess these plants. There was one report from 1990 of 45 *D. newmani* associated with *M. australis* (E. Smith, pers.com. 2012). Despite subsequent extensive fruit collection and insect rearing, there was no subsequent confirmation that *M. australis* was a host of *D. newmani*. Despite this speculation, these species may not be a host or the only host. Field sampling will be required to clarify the uncertainties raised above however funding field sampling may be problematic as *D. newmani* is not an economic pest.

Dacus newmani has a single brood (Gillespie 2003) or two broods at best. By comparison, *Bactrocera tryoni* has five to seven generations per year in the same area (Yonow and Sutherst 1998). *Bactrocera tryoni* can live for at least 11 weeks under ideal laboratory conditions but are unlikely to survive past three days when denied water and nutrition (Dominiak *et al.* 2014). It would be assumed that conditions of privations exist in the arid environments. This raises the question of how *D. newmani* survives from year to year between comparatively few breeding cycles. There may be a dormant phase. If this is the case, it is the egg or more likely the pupal stage that is the dormant stage. *Dacus newmani* may pupate in fruit however these still mature and disintegrate during seed dispersal. Given the host cycle and the challenging dry environment, the mechanism of survival remains an enigma and remains speculation until field investigations find the hosts.

CONCLUSIONS

Research into *D. newmani* has been fragmented because it has never been found infesting commercial produce. It remains an enigma as it has been trapped for nearly a century and yet only the male form is known and described. One female example is known from 1927 and Drew (1989) also studied five female paralectotypes. No hosts are known although a member of Asclepiadaceae (*M. australis*) is speculated to be a host. It is clearly different to the economic fruit flies as *D. newmani* populations proliferate in drier conditions. It is not attracted to wet food lures and only males are attracted to cuelure and similar parapheromones.

However, domestic and international trade in produce continues to develop to feed the world's increasing population. Food security is becoming an increasing concern for many countries and some countries seek assurance that *D. newmani* does not pose a risk to exported produce. This review of *D. newmani* places the current level of knowledge in one publication to allay the concerns of market access partners. This review may also provide assistance in understanding other cryptic Dacinae in semi-arid regions.

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