Summary of presentation at the April 4th National Fruit Fly Council Webinar: Interspecies Competition in Fruit Flies

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History of Mediterranean Fruit fly and Queensland Fruit fly interactions:

Mediterranean Fruit fly (Medfly, *Ceratitis capitata*) was first reported in Australia in Western Australia in 1896, and then subsequently in Victoria and New South Wales in 1898. The species was then reported in Tasmania in 1899.

At the time, the colonial entomologists did not assume that the east-coast Australian infestations came from Western Australia. Instead, that citrus fruits from South Africa were responsible for the incursions in Victoria, New South Wales, and Tasmania.

The outbreak in Tasmania did not survive long. Still, the species became permanently established in various parts of New South Wales, and sporadic outbreaks were reported in Victoria.

After establishing on the east coast, the species became progressively rarer over the next 30 years and has been absent from the eastern states since the 1940s[1].

Queensland Fruit fly (Qfly, *Bactrocera tryoni*) is an endemic species to tropical and subtropical eastern Australia.

The first formal report on its damage from the Toowoomba district of Southeast Queensland was in 1889, but oral statements were from as early as the 1850s.

Fruit fly competitive interactions:

Fruit fly species competitively interact over fruit through contest competition between adults for fruit access and through scramble competition between larvae within the fruit.

The competition of fruit flies is hierarchical; *Bactrocera* species are competitively superior to *Ceratitis* species, which are in turn competitively superior to *Anastrepha* species. Within a genus, species are more competitive with others, e.g. *B. dorsalis* is competitively superior to *B. tryoni*.

Less competitive species are ecologically displaced in time, locality, and host usage.

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[1] *Dominiak, Bernie & Mapson, Richard. (2017). Revised Distribution of Bactrocera tryoni in Eastern Australia and Effect on Possible Incursions of Mediterranean Fruit Fly: Development of Australia's Eastern Trading Block. Journal of economic entomology*

Medfly/Qfly interactions in eastern Australia

The disappearance of Medfly from the eastern coast, and the southward spread of Qfly in the 1920s/30s, have been routinely and repetitively interpreted in the literature as the result of Qfly outcompeting Medfly to the point of extinction. There is no scientific basis for this interpretation.

Only one study[2] has ever conducted a competition experiment on these two species. While he found more Qfly than Medfly emerged from co-infested apples (9 fruit), he showed Medfly did better in co-infested pears (3 fruit). He reported observing that Qfly females "very frequently" used egg punctures made by Medfly females; however, no data was recorded for this observation.

There is no modern study of Medfly/Qfly interactions.

Allman attributes the decline in Medfly numbers in New South Wales to "the enforcement of regulations regarding the picking up and destruction of infested fruit, together with the enforced removal from trees of certain varieties of citrus fruit"[2]

In Victoria, the timeline for the decline of Medfly and the increase in Qfly do not match.

Well-established and highly damaging Medfly populations in Victoria died out from all of Victoria except for rare reports from Melbourne by 1941; Qfly was still only being reported sporadically in the state as late as the 1960s. An almost twenty-year gap that cannot be ignored.

This clearly shows that mechanisms other than competition led to the local extinction of Medfly populations in at least some locations in eastern Australia.

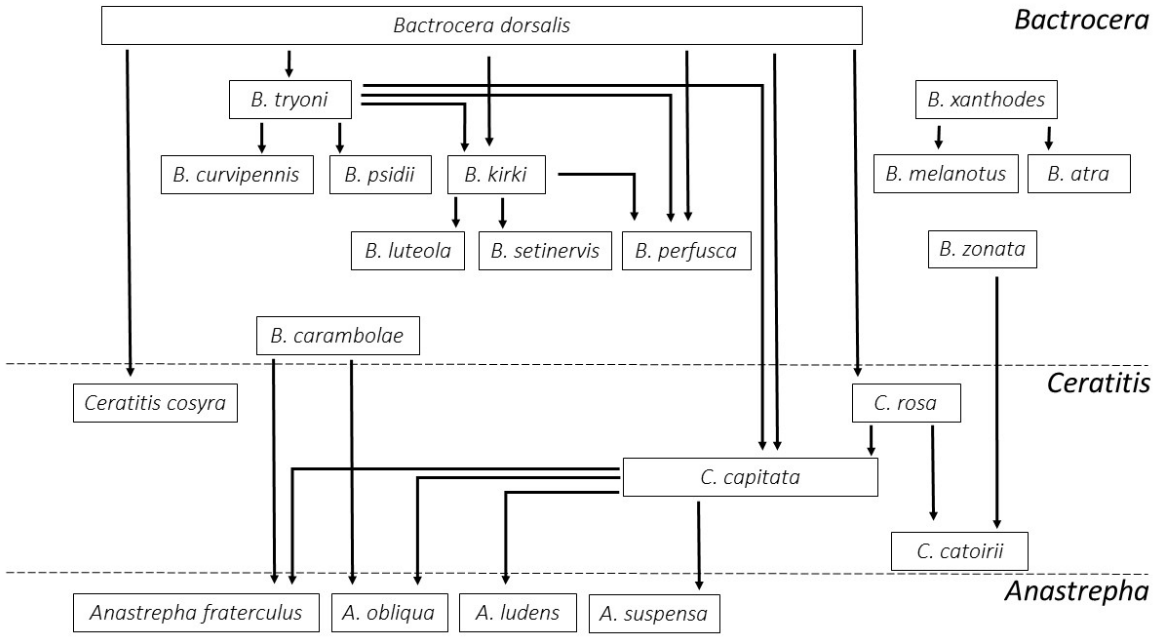
While the international experience with related species strongly supports a hypothesis that Qfly will be competitively superior to Medfly, competition to extinction on continental landmasses and large islands has not ever been observed.

Fruit fly competition and hierarchies

Contest competition occurs when one group of individuals directly interact with individuals of a second group for access to a limited resource. When contest competition persistently favours one competing group over another, it is known as asymmetrical competition. This is prevalent among many insect species, and fruit fly competition falls into this category, with fruit being a limited resource.

A competitive hierarchy exists across the fruit fly genera, with *Bactrocera* species more competitive than *Ceratitis* species, which are more competitive than *Anastrepha* species. Some species are also more or less competitive within a genus than others.

[2] *Allman S.L. 1939. The Queensland fruit fly-observations on breeding and development*

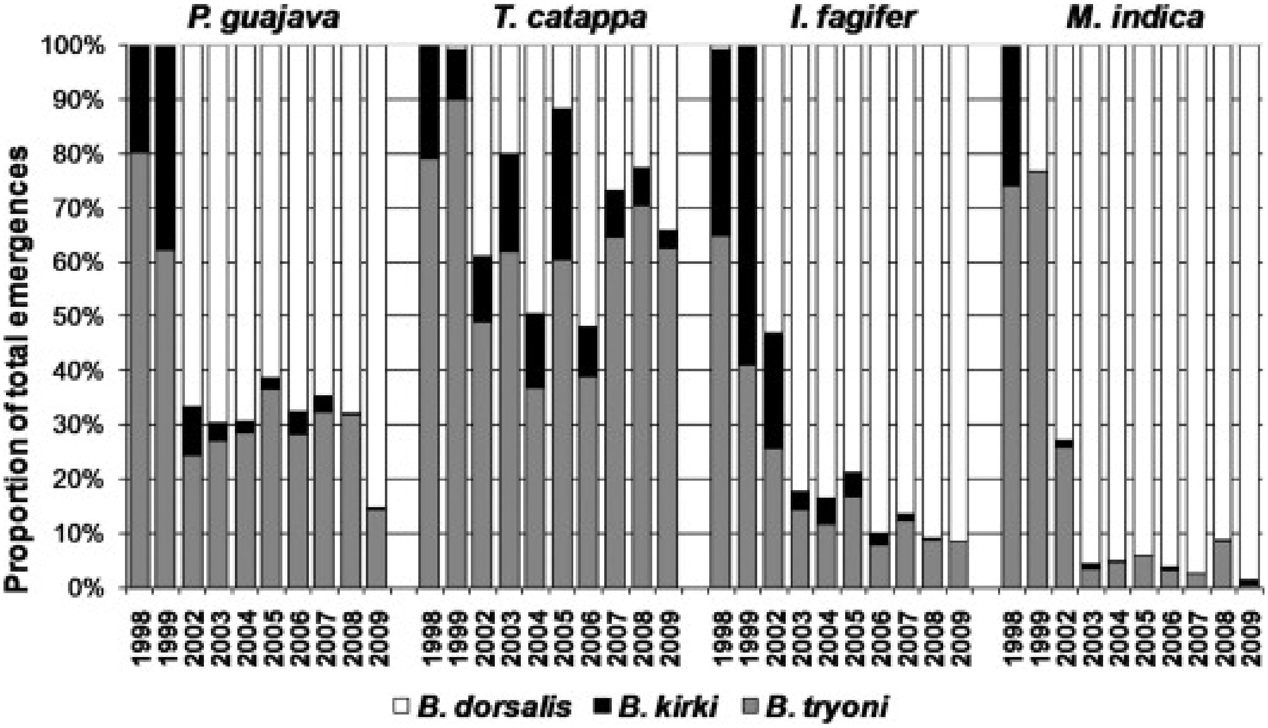


The competitive hierarchy of frugivorous fruit flies (Redrawn from Duyck et al. (2004) and as used in Clarke (2019)).

Numerous studies have shown that fruit fly competition can cause displacement between species. However, eradication has not been recorded. The three main ways studies have shown displacement are:

1. More competitive flies can displace less competitive species in time. In Africa, the Mango Fruit fly (*C. cosyra*) is now an early season mango pest; prior to *B. dorsalis* invading, it was a mid to late-season pest.
2. More competitive flies can displace less competitive species in space. *B. dorsalis* particularly likes lowlands and displaces species altitudinally.
3. More competitive flies can displace less competitive species in host usage. Where host use overlaps, more competitive species will dominate the preferred hosts, leaving less competitive species with less preferred hosts.

The replacement of B. tryoni and B. kirki by B. dorsalis in Tahiti from 1998 to 2009 (from Vargas et al. 2012).



Host effects

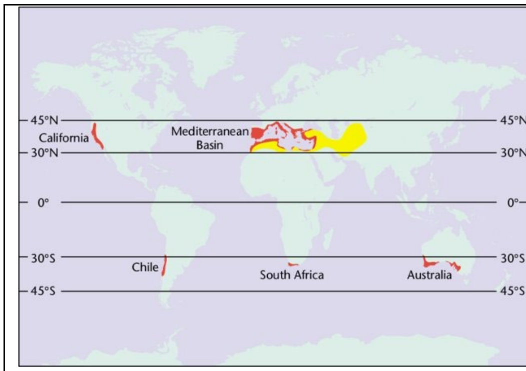
B. tryoni and *B. kirki* almost entirely displaced in mangoes and Polynesian chestnut within two years, surviving better in guava and much better in tropical almond.

Dr. Francis De Lima

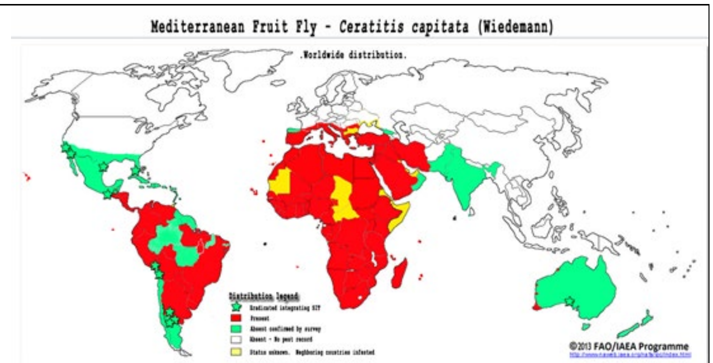
Consultant Entomologist at Aghort Solutions Pty. Ltd.

Mediterranean fruit fly in Australia and overseas: distribution, demography, dispersal and management

The Mediterranean Fruit fly (Medfly, *Ceratitis capitata*) originated in Africa and has been distributed to various countries where the Mediterranean climate exists. This includes the Mediterranean basin and adjacent to the Middle East, California, South America, South Africa and Western Australia.



Five regions with Mediterranean-type climate. (Le Houe´rou Houe´rou, 1997)



Where Medfly is established for quarantine purposes (RED), was breeding (star green), is absent (green) (FAO / IAEA 2013)

Origin and spread of Medfly in Western Australia

Medfly was first reported in Perth in 1896; eradication measures were implemented; however, this was unsuccessful, and the flies dispersed and spread to the north and south.

In 1908 Cold treatment and Fumigation were introduced to enable orchards to survive economic loss; subsequently, the Department of Primary Industries and Regional Development in Western Australia had 25 full-time fruit fly inspectors employed to enforce eradication and control until 1988.

Large scale eradication efforts have been tried several times over the past 125 years, costing large sums and with no success.

The climate across Western Australia differs significantly, but the species has adapted to the environments; it is now established from Esperance in the south to Derby in the north, with the highest populations between Bunbury and Carnarvon.

Temperature supports Medfly development, and rainfall supports cultivated & native hosts.

All recorded temperatures in Western Australia and the country, more widely, are suitable for Medfly development, including the eastern states.

As seen in the table below, many studies around the world have established the minimum temperature for Medfly growth at different life stages:

Development Thresholds, °D, Optima & Survival Limits

Temperature developmental thresholds Th, Deg Days°D, Survival °C extremes

Stage	De Lima (2008)		USDA* Medfly Action Plan		Gutierrez & Ponti (2011)		Vargas et al. 1884	
	Th °C	°D	Th °C	°D	Th °C	°D	Th °C	°D
egg	9.3	44	-	-	10.5	31		27.5
larva	11.1	162	10	176.6	10.5	97	13.7	117.4
pupa	8.4	156	11.6	138.6	9.5	165		233.9
pre-oviposition	12.8	36	15.7	60.4	9.5	48		
total °D		398		375.6		341		378.8

50% Survival °C	
lower	upper
-1	44
-1	44
-1	44
-1	40

Optimum °C For Medfly Population Growth = 24-30 °C (all stages)

Average Temperatures across WA, Australia, World (33yrs)

Optimum °C for Medfly population growth is 24 - 30°C
33 year average temperatures 1988 - 2020.

	Min °C	Max °C	Av. °C
Perth	13	25	19
Donnybrook	10	24	17
Manjimup	10	21	16
Kununurra	21	35	28
Broome	22	32	27
Carnarvon	17	28	23

Optimum °C for Medfly population growth is 24 - 30°C
33 year average temperatures 1988 - 2020.

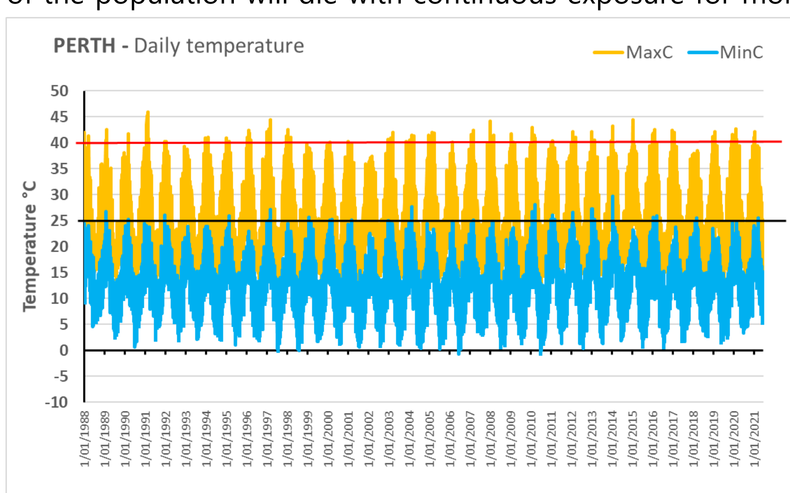
Place	Min °C	Max °C	Av. °C
Adelaide	12	22	19
Melbourne	10	20	15
Sydney	15	23	19
Hobart	8	18	13
Launceston	6	18	12

Place	Min °C	Max °C	Av. °C
Greece, Thessaloniki	10	20	15
USA, Los Angeles	14	24	19
Israel, Tel Aviv	14	25	20
Italy, Calabria	15	22	18
Kenya, Nairobi	14	24	19
South Africa, Cape Town	14	20	17
Chile, Santiago	10	22	16

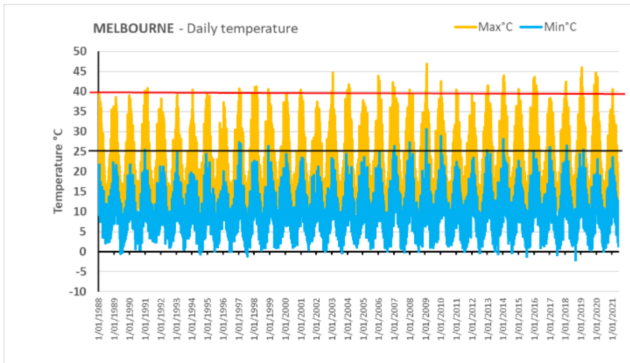
**These places have established Medfly Populations*

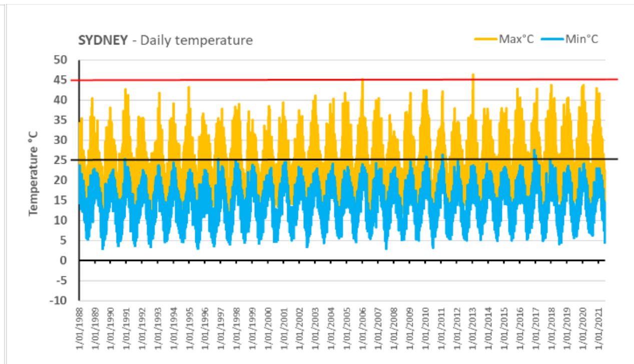
Eggs will begin to develop when temperatures reach above 9.3 degrees Celsius, an easily achievable temperate across Australia. Another critical temperature range is 24-30 degrees Celsius, where we see explosive growth for all stages. Finally, a lower temperature bound of -1 degrees, where 50% of the population will die over two days, and an upper temperature bound of 44 degrees Celsius where 50% of the population will die with continuous exposure for more than 6 hours.

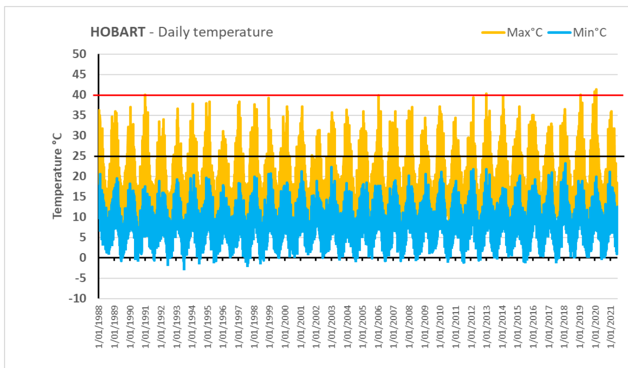
When looking at the historical daily temperatures for the last 33 years in Western Australia, clear evidence shows us that the climate is consistently suitable for Medfly throughout the year.



Australia wide, the historical daily temperatures for the last 33 years also show that the species could easily survive in almost all regions.

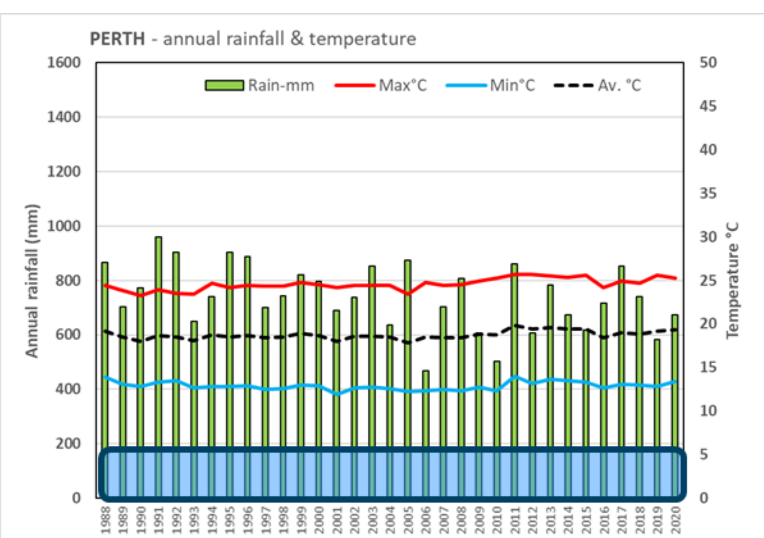


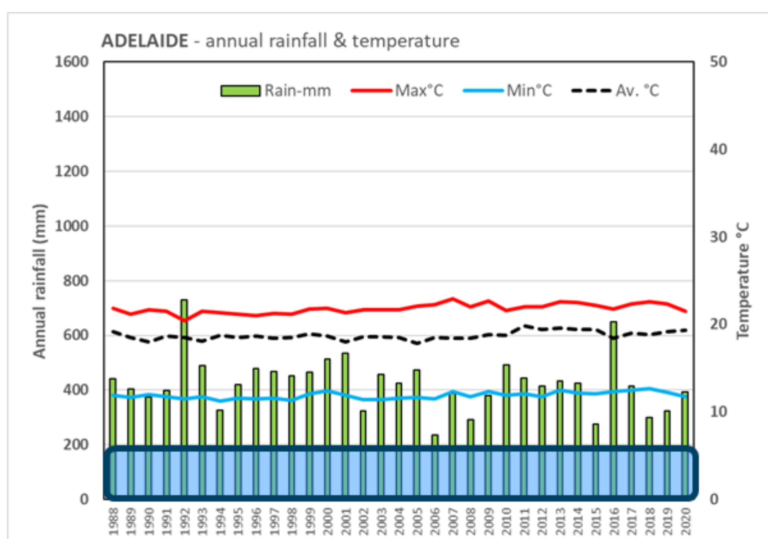




Historical rainfall data and native host growth show a similar story across Western Australia and the country.

Native hosts only require 200mm of rainfall for growth; shown below is the average annual rainfall for the last 33 years; most of Western Australia supports native host growth throughout the year, allowing permanent native hosts to be available across the year. Compared to Adelaide, which has had recent outbreaks, the average rainfall also allows for year-round native hosts.





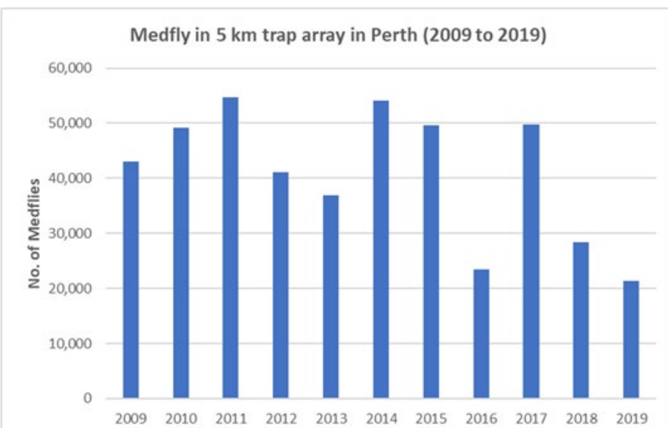
The current state of Medfly in Western Australia

Perth has a very strong host base for an established and persistent Medfly population. If we look at the availability of these hosts over the year we can see

1. Larval hosts are available throughout the year, and
2. Adults also have suitable sites throughout the year

HOST PHENOLOGY PERTH	SPRING			SUMMER			AUTUMN			WINTER		
	O	N	D	J	F	M	A	M	J	J	A	S
LARVAL HOSTS												
CITRUS												
STONE FRUIT												
OTHER GOOD HOSTS												
POOR HOSTS												
ADULT HOSTS												

Trapping data over 10 years also shows a persistent Medfly population.

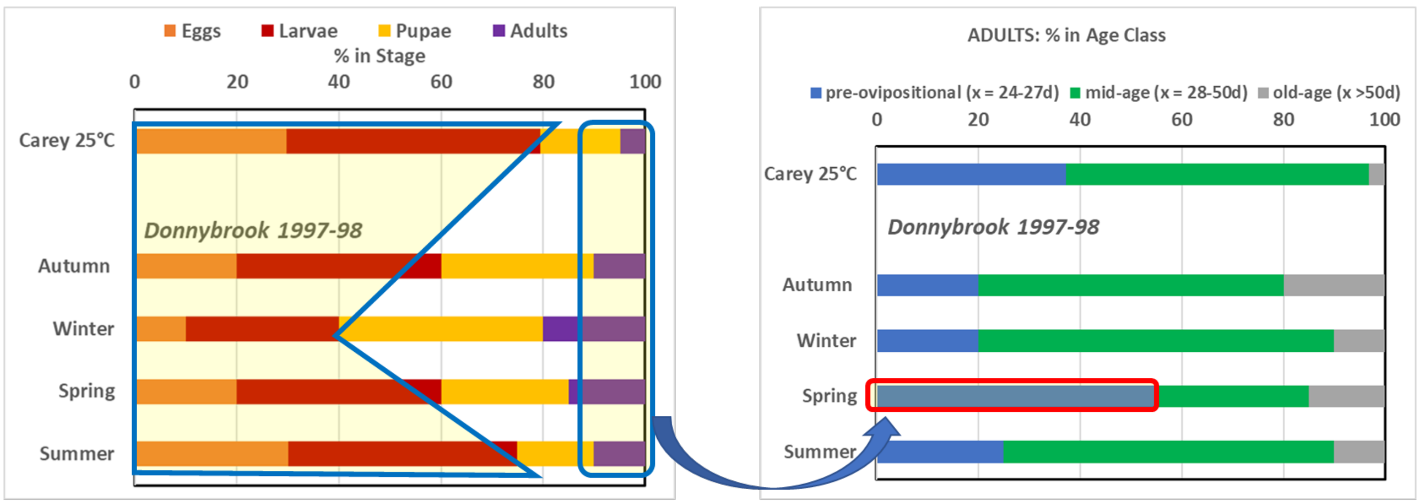


Control & Demography Population Stage and Age Structure

The graph below compares Carey's 1982 laboratory data with the field populations from Donnybrook. This shows that in any season, the majority of the population is in the immature stages. However, compared to Carey's data, the proportional field adult population is larger

Historically the treatment of immature stages has been covering sprays, but they are not always effective. Cover spraying is also quite damaging to the ecosystem, animal, and human health. Many products have been banned due to this.

A more effective approach has been to target the adult population, using baits. An analysis of the adult age structure over the seasons shows that the highest proportion of pre-ovipositional females appears in spring. A treatment targeting these females, especially considering each female carries 300 female eggs, is a powerful way to control the lifecycle with minimal environmental impact.



- Eggs and Larvae in Fruit
- Pupae in the ground
- Adults in the canopy

Control Strategies:

- Cover spraying (banned)
- Eradication (not successful in WA)
- Bait spraying (recommended)

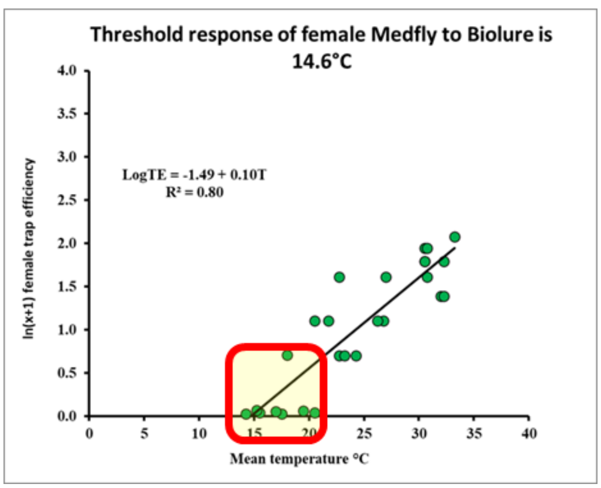
Bait Treatment

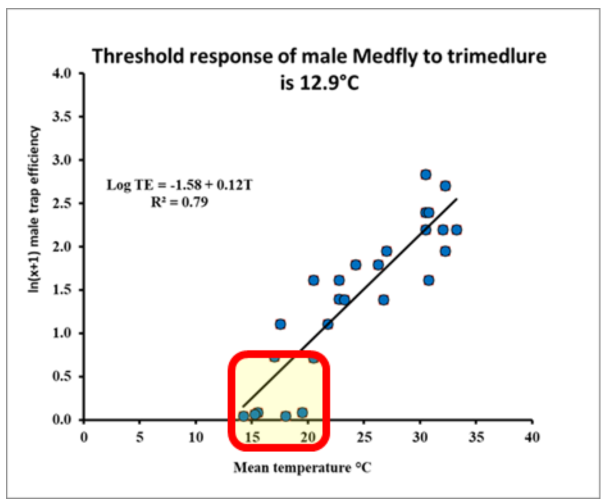
Using traps to detect adult Medfly populations is highly ineffective. Traps have been proven to only represent approximately 1% of adult Medfly populations and the adult population represents only 10-20% of the total population. This means that using trap data is often a significant underestimate of the actual population.

Traps are also not very effective below 20 degrees Celsius, as shown in the graphs below for both males and females.

On this basis, threshold numbers were set as a bait control treatment for growers in 1996 and have since been used for effective control.

Action thresholds: x represents the number of flies/ha/week/ 2 traps male+female		
State	**x = No. flies/ha/week**	**Action**
(i)	**x = 0**	**no action is required**
(ii)	**0 < x < 1**	**weekly orchard perimeter baiting**
(iii)	**1 ≤ x <2**	**weekly whole orchard baiting**
(iv)	**2 ≤ x <3**	**twice weekly whole orchard baiting**
(v)	**3 ≤ x <4**	**twice weekly whole orchard every tree baiting x 2 weeks**
(vi)	**x ≥ 4**	**twice weekly whole orchard baiting until population drops below 4 flies.**

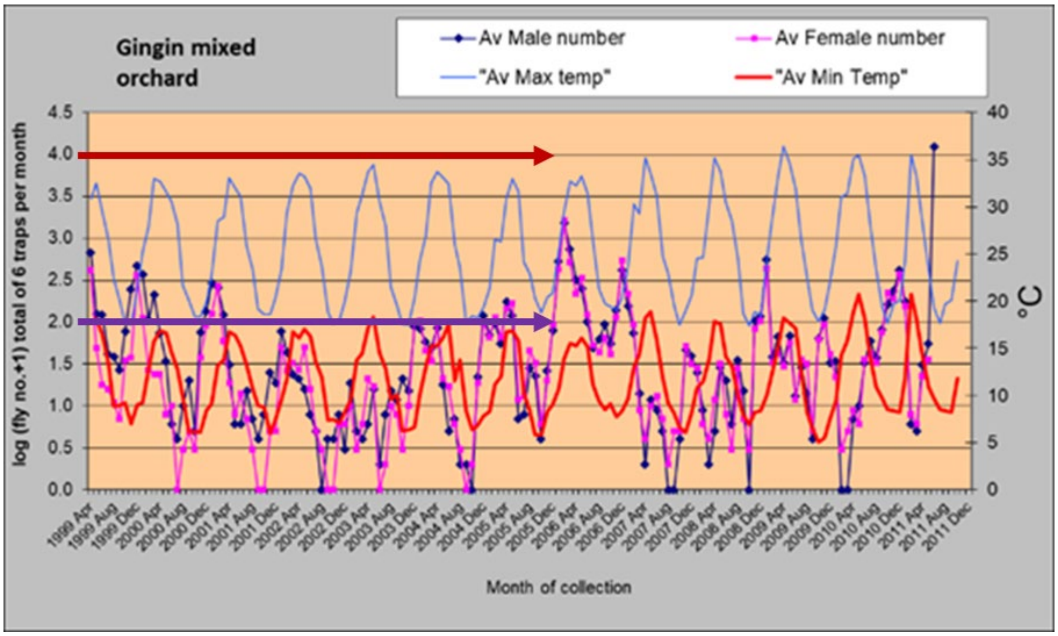


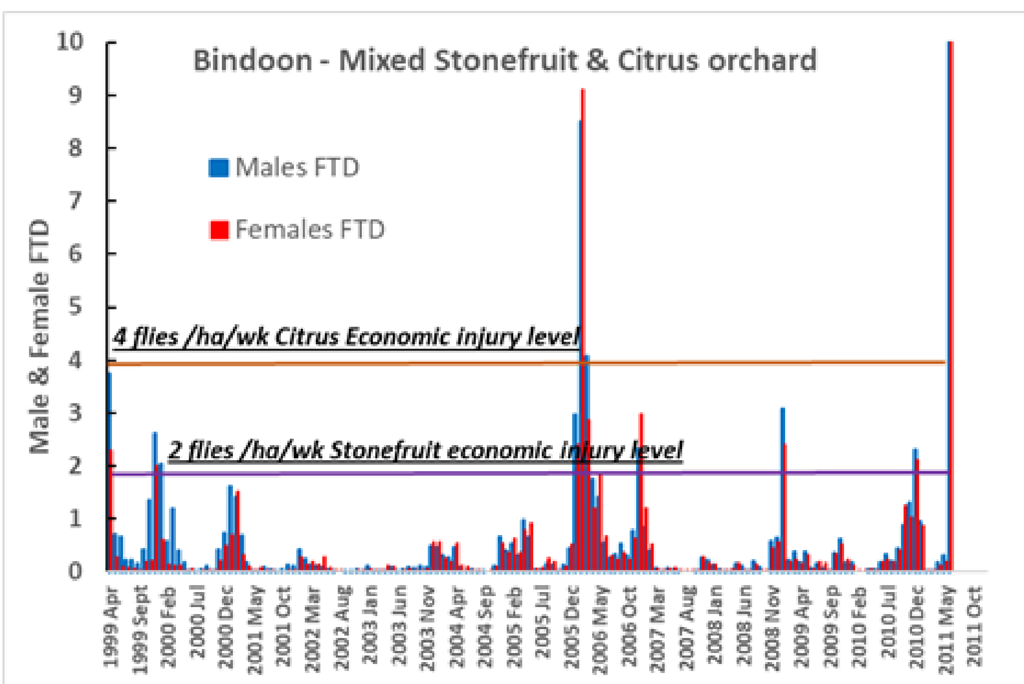


Protein + Pesticide Baits – Gingin & Bindoon (12yrs)

These graphs show the Medfly population in mixed citrus and stone fruit orchards in Gingin and Bindoon that have been subject to a Bait Treatment Plan. These areas have a higher rate of Medfly population growth than Perth and the South West - mostly due to higher average temperatures (min above 5C and Max hits 35C which is near Optimum)

Despite this, these growers were able to consistently maintain the Medfly population below 4 flies for over 12 years.





Summary

The experience of Medlfy in Western Australia matches that of other areas in the world where Medfly is not native. It is well adept at adapting to different climates, as is evident in Western Australia.

The species is difficult to eradicate, it can be managed below a level of economic injury, however this takes consistent upkeep and maintenance.