Predictive phenological modelling and the DAWE project "*Phenology, demography and distribution of Australia's fruit flies*"

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Background

- As traditionally used in applied entomology, predictive population models are valuable to growers for the timing of interventions.
- For market access, justified reinstatement dates in an area-free zone are predicated on predicting future generation times.
- As part of invasion and landscape risk models, the inclusion of an underlying population model is increasingly recognised as essential for generating accurate predictions.

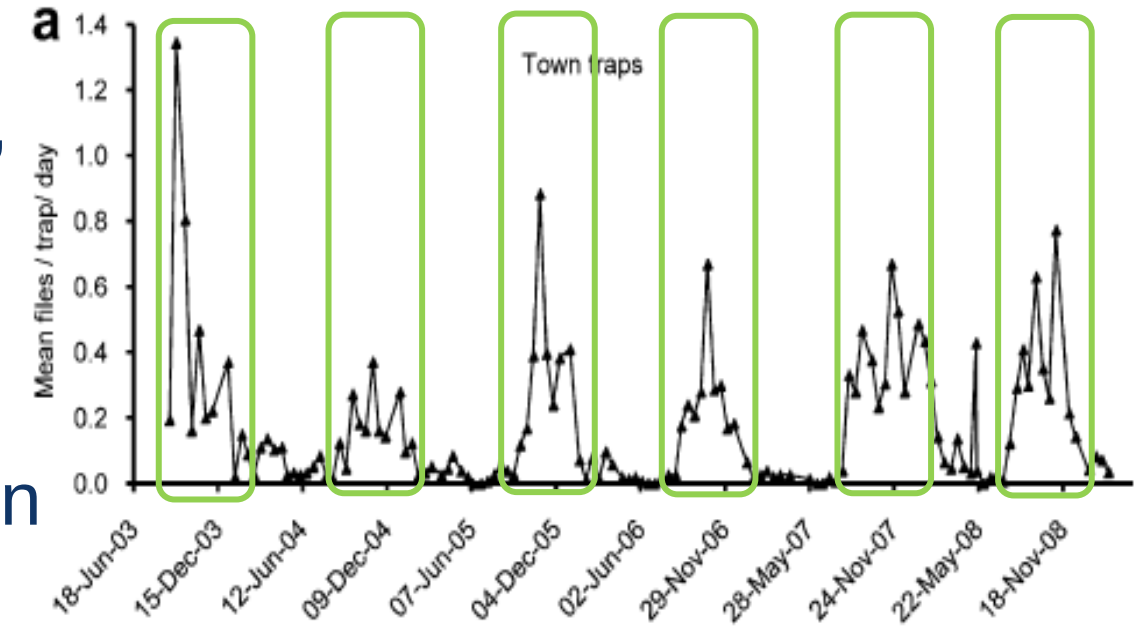
Background

- An accurate, predictive phenological model for *B. tryoni,* or indeed any polyphagous tropical fruit fly, is not available.
- The best known such model, the temperature-driven Dymex model of Yonow et al. (2004), achieved correlation (r) values of 0.16 to 0.36 between observed and predicted data for 3 temperate sites which were climatically similar to the model calibration sites.
- But when 9 tropical and subtropical sites were tested, only 1 site had a significant correlation (r = 0.24) between observed and predicted, 6 produced non-significant correlations, and 1 had a significant negative correlation! (Muthuthantri et al. 2010)
- This strongly suggests the model is flawed in its basic assumptions.

Yonow et al. 2004. Modelling the population dynamics of the Queensland fruit fly: a cohort-based approach incorporating the effects of weather. *Ecol. Modelling*, **173**,9-30.
Muthuthantri et al 2010. The seasonal phenology of *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae) in Queensland. *Aust. J. Ent.,* **49**,221-233.

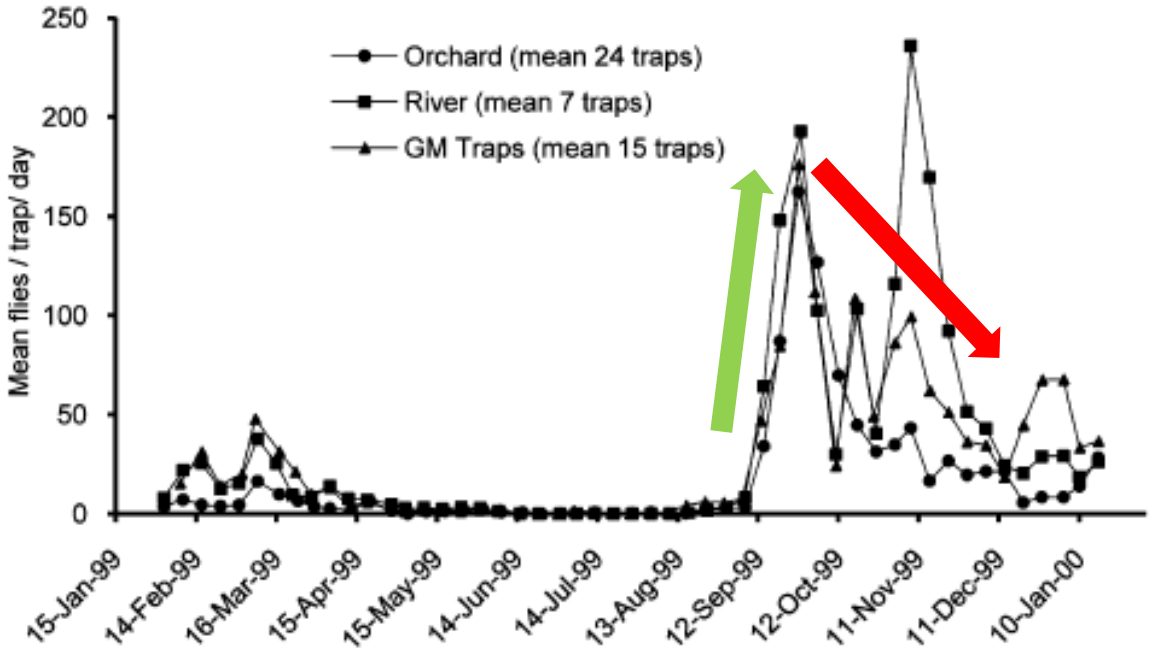
Background

- You might reasonably ask '*what's so hard?'.*
- Qfly has highly seasonal dynamics, that are routinely referred to as the spring/summer active-period and the winter off-period.
- Unfortunately its not so simple when you look more closely.



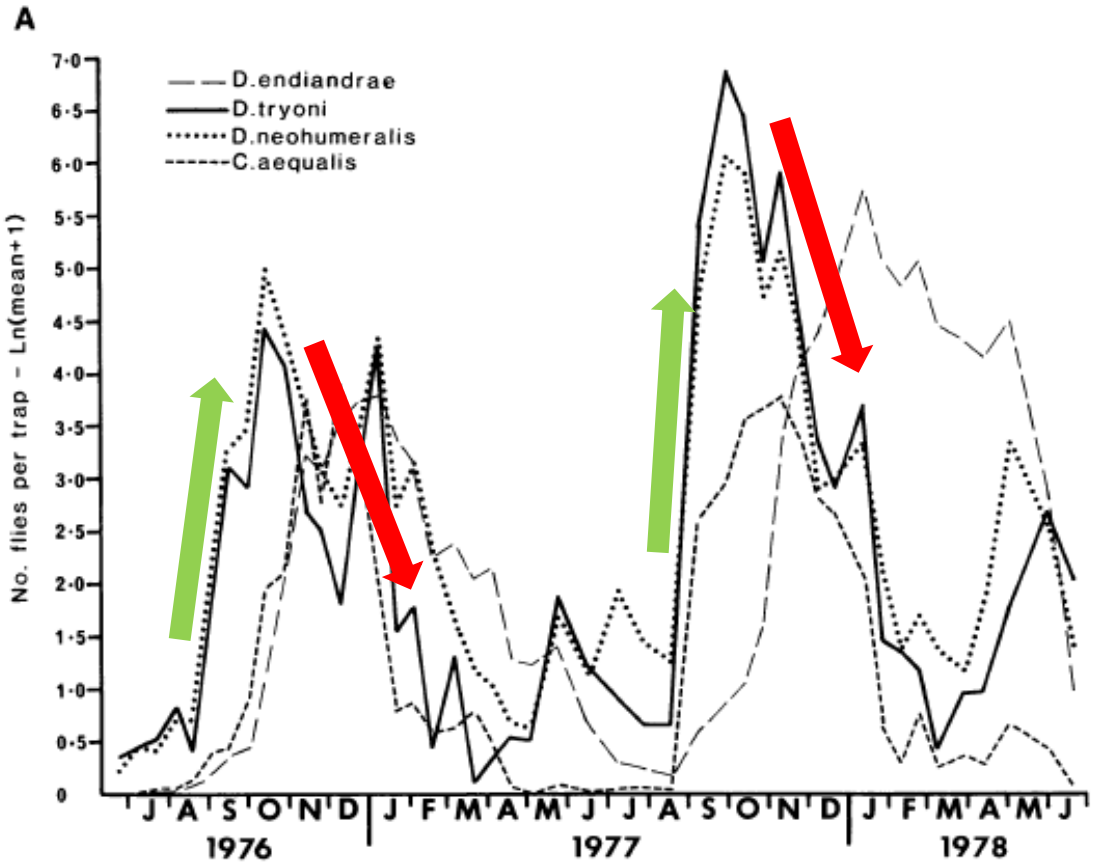
from Lloyd et al (2010)

Lloyd et al. 2010. Area-wide management of fruit flies (Diptera: Tephritidae) in the Central Burnett district of Queensland, Australia. *Crop Protection*, **29,**462-469.



Dynamics in a sub-tropical production area

from Lloyd et al (2010)



Dynamics in a sub-tropical rainforest

from Drew et al (1984)

Lloyd et al. 2010. Area-wide management of fruit flies (Diptera: Tephritidae) in the Central Burnett district of Queensland, Australia. *Crop Protection,* **29,** 462-469.
Drew et al. 1984. Ecological studies of eastern Australian fruit flies (Diptera: Tephritidae) in their endemic habitat. I. Temporal variation in abundance. *Oecologia*, **64**, 267-272.

from Yonow et al. (2004)

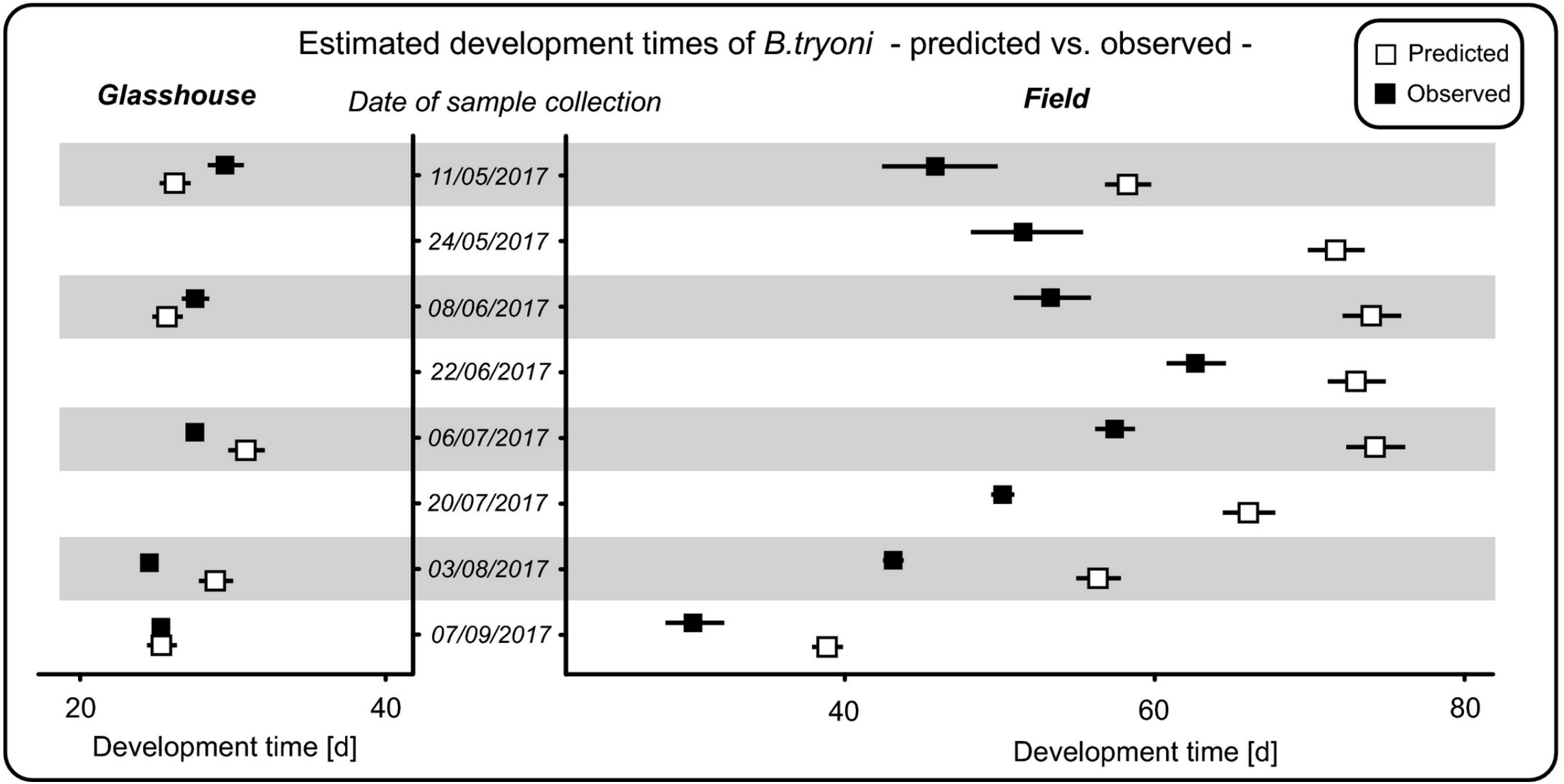
- "*The various mechanisms tested indicate that over-wintering is not just temperature-dependent, but is probably linked to a variety of factors, including temperature, fruit availability and fruit suitability.*"
- *"Day length per se and a directional change in day length are both unlikely cues…"*
- *"Until the mechanisms determining the onset and the ending of over-wintering are understood, it will be difficult to improve on the model predictions…"*

Yonow et al. 2004. Modelling the population dynamics of the Queensland fruit fly: a cohort-based approach incorporating the effects of weather. *Ecol. Modelling*, **173**,9-30.

Constant-temperature development rate

- Independent of seasonal patterns in the field, CT development rates are also just poorly known.
- For Qfly, the maximum number of constant temperatures used in single study was 3, and that study assessed variation in total generation time (Bateman 1967).
- A classical constant temperature/development rate study does not exist for any native Australian fruit fly, including Qfly.

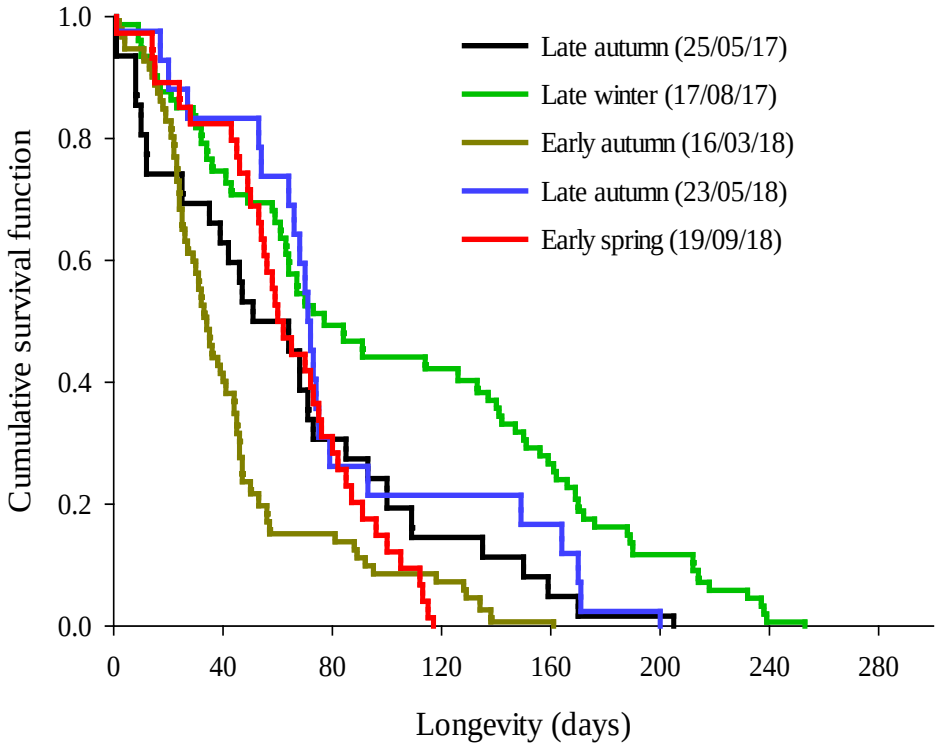
Bateman 1967. Adaptations to temperature in geographic races of the Queensland fruit fly, *Dacus* (*Strumeta*) *tryoni*. *Aust. J. Zool.,* **15**,1141-1161.



from **Merkel et al.** 2019. "Overwintering" phenology of a polyphagous, tropical fruit fly (Diptera: Tephritidae) at the sub-tropical/temperate interface. *J. Appl. Ent., 143*, 754-765.

…and just to confuse things further

- Longevity of Qfly varies with season, even when flies are held at a constant temperature (Tasnin et al. 2021)
- Time to sexual maturation in female Qfly varies across the year independently of ambient temperatures (Pritchard 1970)



from Tasnin et al (2021)

Tasnin et al. 2021. A polyphagous, tropical insect herbivore shows strong seasonality in age-structure and longevity despite temperature and hosts not being limiting. *Sci. Reports,* **11,**11410.
Pritchard 1970. The ecology of a natural population of Queensland fruit fly, *Dacus tryoni* III. The maturation of female flies in relation to temperature. *Aust. J. Zool.,* **18,**77-89.

The Smart Fruit Fly Management Measure

- Under the Commonwealth's Smart Fruit Fly Management Measure, the project "*Phenology, demography and distribution of Australia's fruit flies*" is helping to fill some of the these knowledge gaps through data collation, data generation, and data analysis.
- Target species *Bactrocera tryoni*, *B. neohumeralis*, *B. jarvisi*, *B. aquilionis*, *Zeugodacus cucumis* and *Dirioxa pornia*
- Project lead CI: Peter Leach, QDAF Cairns

Activity 2: Demographic studies

- Generate and analyse longevity and fecundity data for all target species reared on a standard diet, plus one “good” host and one “poor” host (as judged by offspring performance).
- NT, QLD, NSW, SA, WA
- Lead scientist: Dr Natalia Souza, QDAF Cairns
- Status: research underway

Activity 4: Day-degree models

- Generate and analyse constant-temperature/development-rate data for all target species reared on a standard diet, plus one “good” host and one “poor” host.
- NT, QLD, QUT, SA, WA
- Lead scientist: Dr Le Hoan, QDAF Cairns
- Status: research underway

Activity 5: Collate and analyse field phenology data

- Generate and analyse existing trapping data sets for *B. tryoni* and other species as available.
- NT, QLD, QUT, NSW, Vic, SA, WA
- Lead scientist: Dr Vesna Gagic, QDAF Brisbane
- Status: Data collated and cleaned (>2mill rows of data, where a row is single trap collection), statistical modelling to analyse long-term (multi-year) and short-term (within year) phenological patterns, and spatial patterns of abundance, is underway. [NB, not predictive modelling]

Activity 8: Detailed phenology and demography of Qfly

- Generate and analyse new data for *B. tryoni* focusing on the spring emergence and summer decline. Using demographic, physiological and molecular approaches to understand phenology. Working hypothesis is that the ‘winter’ decline is not temperature mediated, as it occurs in both tropical and temperate Australia.
- QLD, QUT, NSW, Vic.
- Lead scientist: Dr Shahrima Tasnin, QDAF Brisbane
- Status: Ongoing, different lines of research underway in multiple locations.

Timelines

- Research through to Feb/March 2022
- Final reporting [including submission of data sets] April/May 2022
- Publish non-confidential information during 2022

Take home message

- The historical focus of studying the biology of Qfly in temperate Australia has led researchers to forget that *Bactrocera* are insects which evolved in monsoonal, tropical rainforests.
- The phenological drivers of monsoonal insects (rainfall, RH, host availability) are very different to the phenological drivers of temperate insects, where temperature dominates.
- *You can take the fly out of the rainforest, but can you take the rainforest out of the fly?*

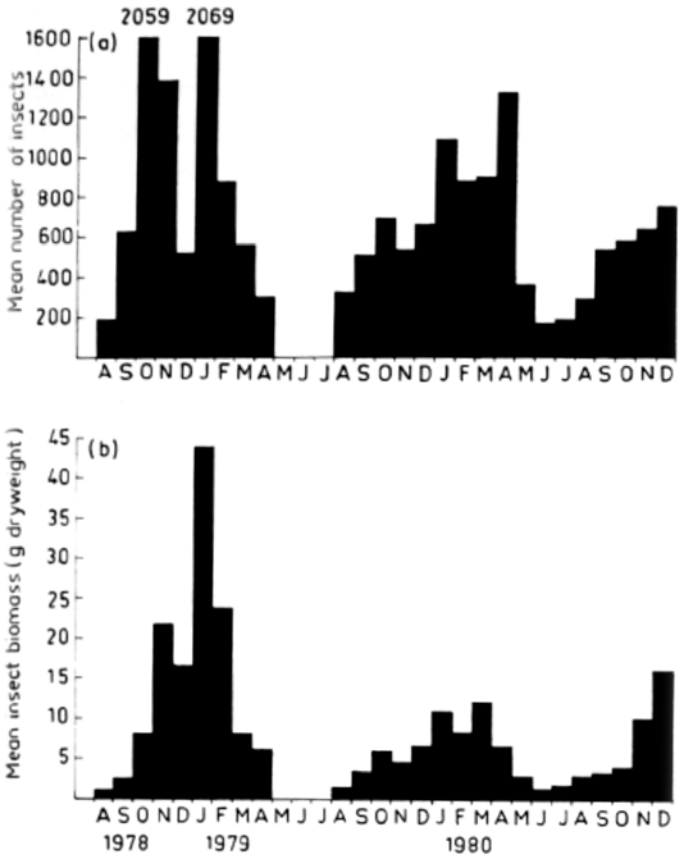


FIG. 3. Seasonality of (a) numbers and (b) biomass of insects sampled by a light trap in the study site, August 1979 to December 1981. No data were available for May–July 1979; see Methods.

Fig 3 from **Frith & Frith** 1985. Seasonality of insect abundance in an Australian upland tropical rainforest. *Aust. J. Ecol.,* **10**,237-248.

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Australian Government

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