Data-informed mathematical models for predicting locust hopper band movement and optimising control

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AAGI Analytics for the Australian Grains Industry

The Problem

Australian plague locust nymphs march in dense hopper bands, eating crops as they go and causing huge losses. Control today relies largely on blanket spraying.

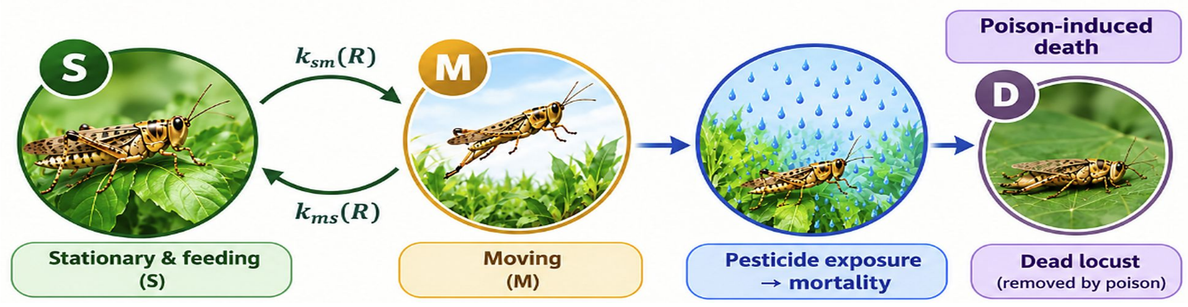
Objective: predict how bands move, then design barrier strips that cut cost and time and avoid crop loss.



Figure 1. A locust hopper band (Hunter et al. 2008).

Why it matters: one of the five most damaging invertebrate pests of Australian grain (Murray et al. 2013). Barrier spraying treats only narrow strips ahead of bands, using less insecticide than blanket spraying.

Methods



Band model

$$S_t = k_{ms}(R)\, M - k_{sm}(R)\, S - \mu(P)\, S$$
$$M_t = -c\, M_x + k_{sm}(R)\, S - k_{ms}(R)\, M$$
$$R_t = -\lambda\, R\, S$$

Red: terms added for the poison strip

Adding a poison strip

$$\mu(P) = \mu_{max}\, P^h / (K^h + P^h)$$
$$P = P^+\, \chi(x)\, R\, e^{-at}$$

$\chi(x) = 1$ inside the strip, 0 outside

The band travels as a wave

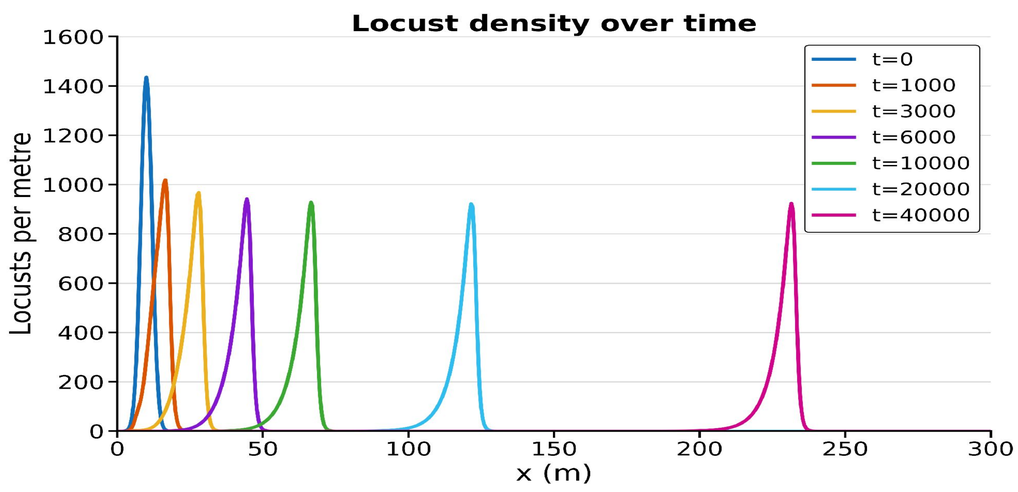


Figure 2. Locust density at successive times in the absence of poison: the band forms a pulse that keeps its shape and speed.

Band crossing a poison strip

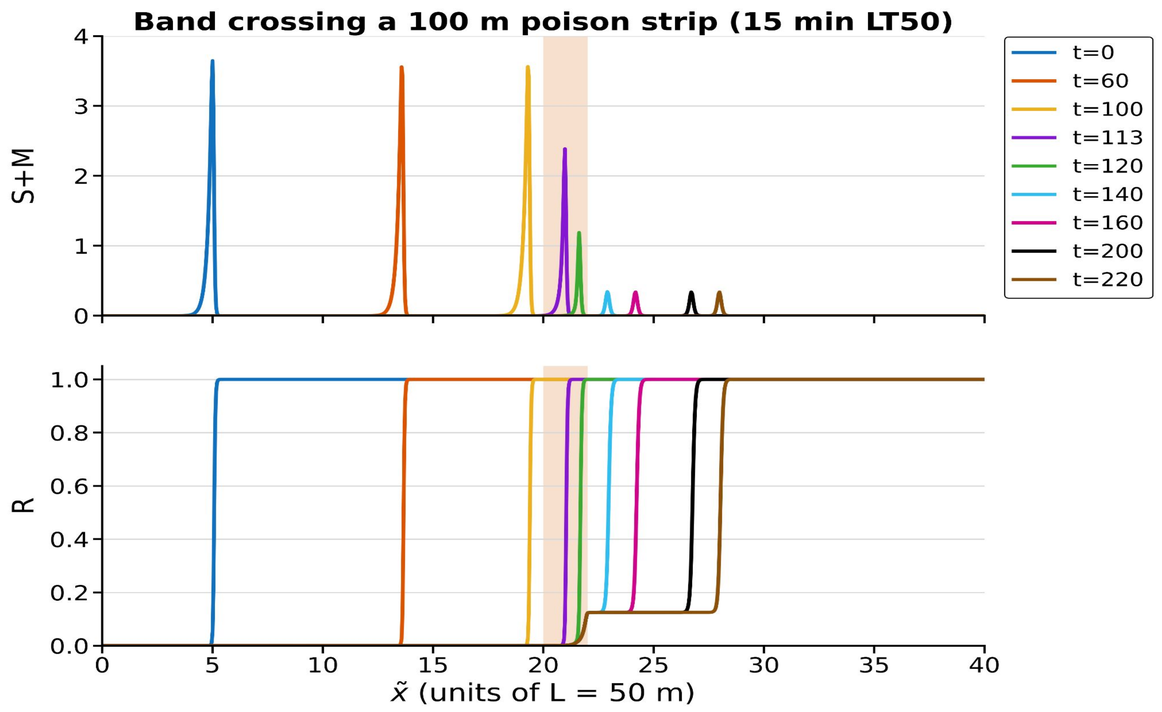


Figure 3. A hopper band crossing a 100 m pesticide barrier strip (shaded). Top: locust density S + M. The band marches at a constant shape and speed, shrinks inside the strip, then re-forms as a smaller band. Bottom: crop R, eaten behind the band. Survivors leave some crop uneaten after the strip.

The effect of strip width

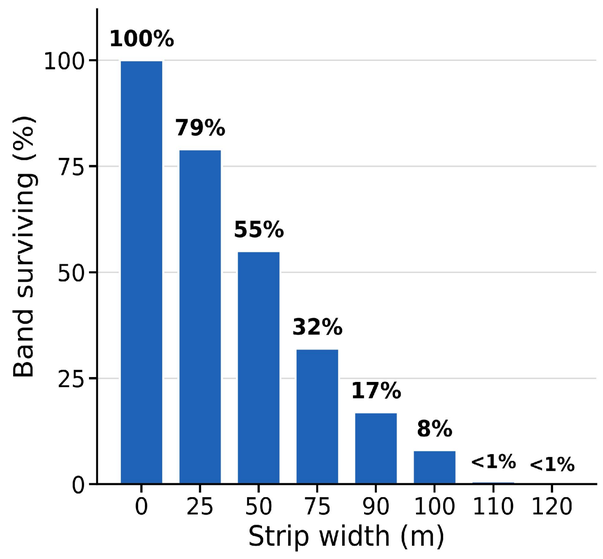


Figure 4. Share of the band surviving a poison strip, by strip width. A 100 m strip leaves 8%; strips of 110 m or more leave under 1%.

Conclusion

Barrier spraying kills most of a band and slows the rest. A 100 m strip kills 92% of the locusts; the 8% that survive re-form a smaller band that marches at less than half its original speed.

Next steps

1. **Control:** Delayed kill; poisoned locusts stop feeding and marching. Insecticides and biopesticides
2. **Realistic bands:** Hunger, age, patchy food, and the minimum density to keep marching
3. **Data:** Lab and drone observations to estimate parameters and test predictions
4. **Optimise:** Width, spacing and product: most crop saved for least product, as simple decision rules

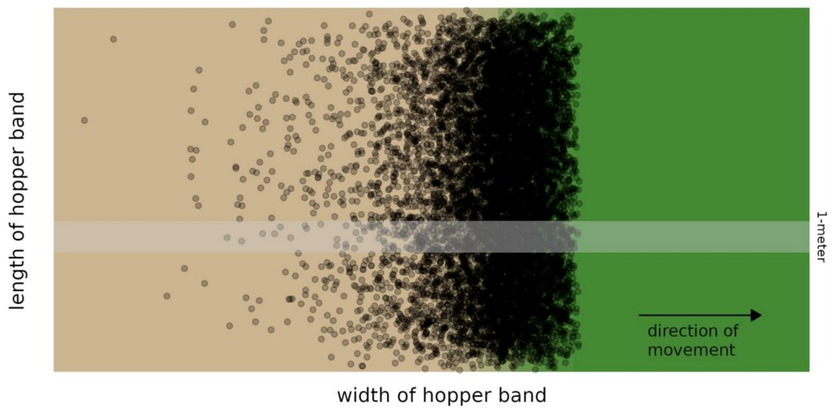


Figure 5. Two approaches: continuum models for whole bands, agent-based models for individuals and tracking data. Image: Bernoff et al. (2020)

Industry impact

- **Cost-effective control**
- **Reduced crop losses**
- **Environmental protection**

Supports targeted, cost-effective and sustainable locust management to help protect grain yields and grower profitability across the Australian grain industry.

References

Bernoff, A. J., Culshaw-Maurer, M., Everett, R. A., Hohn, M. E., Strickland, W. C., & Weinburd, J. (2020). *PLOS Computational Biology*, 16(5), e1007820.

Hunter, D. M., McCulloch, L., & Spurgin, P. A. (2008). *Crop Protection*, 27(1), 118–123.

Murray, D. A., Clarke, M. B., & Ronning, D. A. (2013). *Australian Journal of Entomology*, 52(3), 227–241.

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