Insights from Agriculture for Insecticide Resistance Management

Overview of interdisciplinary workshop held at Penn State, Sept 1-2, 2015.

The workshop

Combined mix of researchers who think about resistance evolution from diverse perspectives: public health, agriculture (insects and weeds), theoreticians, empiricists, lab, field, industry and policy….

Rick Roush
Fred Gould
Jeff Scott
Dave Mortensen
Shirley Luckhart
Mike Strand
Matt Thomas

Andrew Read
Penny Lynch
Ian Hastings
Martin Donnelly
Jeff Bloomquist
Mark Hoppe
Mike Macdonald

The current GPIRM action plan is built around 5 key (interrelated) pillars:

(i) IRM Strategies
(ii) Monitoring
(iii) New Tools
(iv) Knowledge
(v) Enabling mechanisms

Here I use these pillars to structure the insights and ‘recommendations’ from the workshop (note that this is my interpretation of things so not everyone would necessarily agree……)

(i) IRM Strategies

The greater the exposure to an insecticide the greater the selection pressure for resistance.

The most far-reaching approach to address this issue in agriculture has been the development of Integrated Pest Management strategies that aim to minimize the reliance on insecticides.

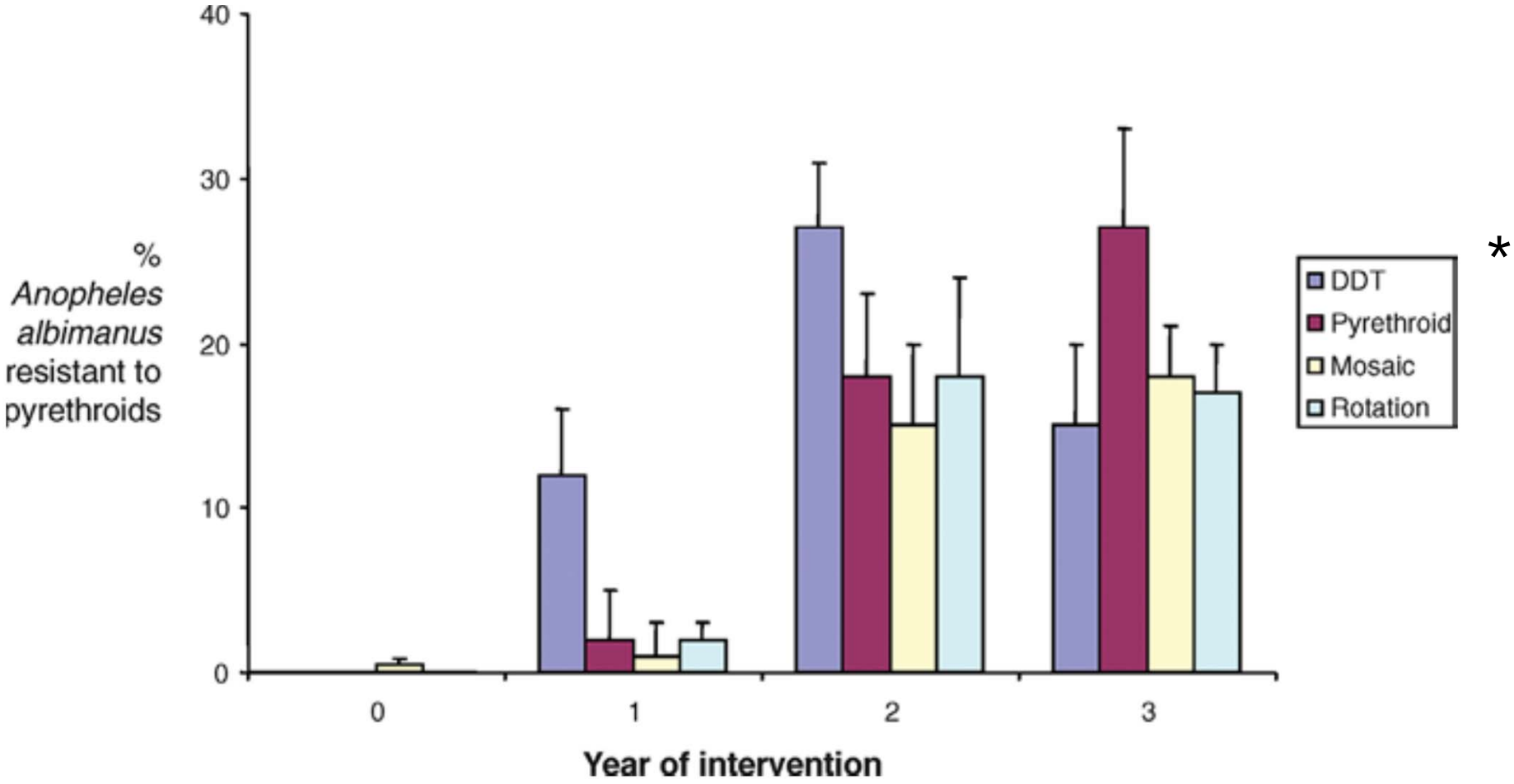
The pending resistance crisis for disease vectors creates an urgent need to develop and implement integrated, multi-tactic IVM strategies that parallel IPM in agriculture.

Numerous studies in agriculture show that IRM strategies that utilize diverse insecticide products over time and space can slow resistance evolution (e.g. rotations, mixtures, mosaics).

However, which strategy works best depends strongly on the specifics of the insect genetics, population dynamics and behavior. There is no general rule.

There are few theoretical examinations of these strategies for disease vectors and next to no empirical tests.

In the absence of this information there is no convincing evidence base for recommending one strategy over another.



doi:10.1371/journal.pbio.1000058.g004

Figure 4. Evolution of Insecticide Resistance over Three Years of Indoor Residual Spraying in Coastal Southern Mexico.

Pyrethroid resistance was assessed using WHO susceptibility bioassays before intervention (year 0) and over three years of different insecticide spraying regimes. Redrawn from [25].

* Mosaic = OP + Pyrethroid

Rotation = OP, Pyrethroid, Carbamate

(ii) Monitoring

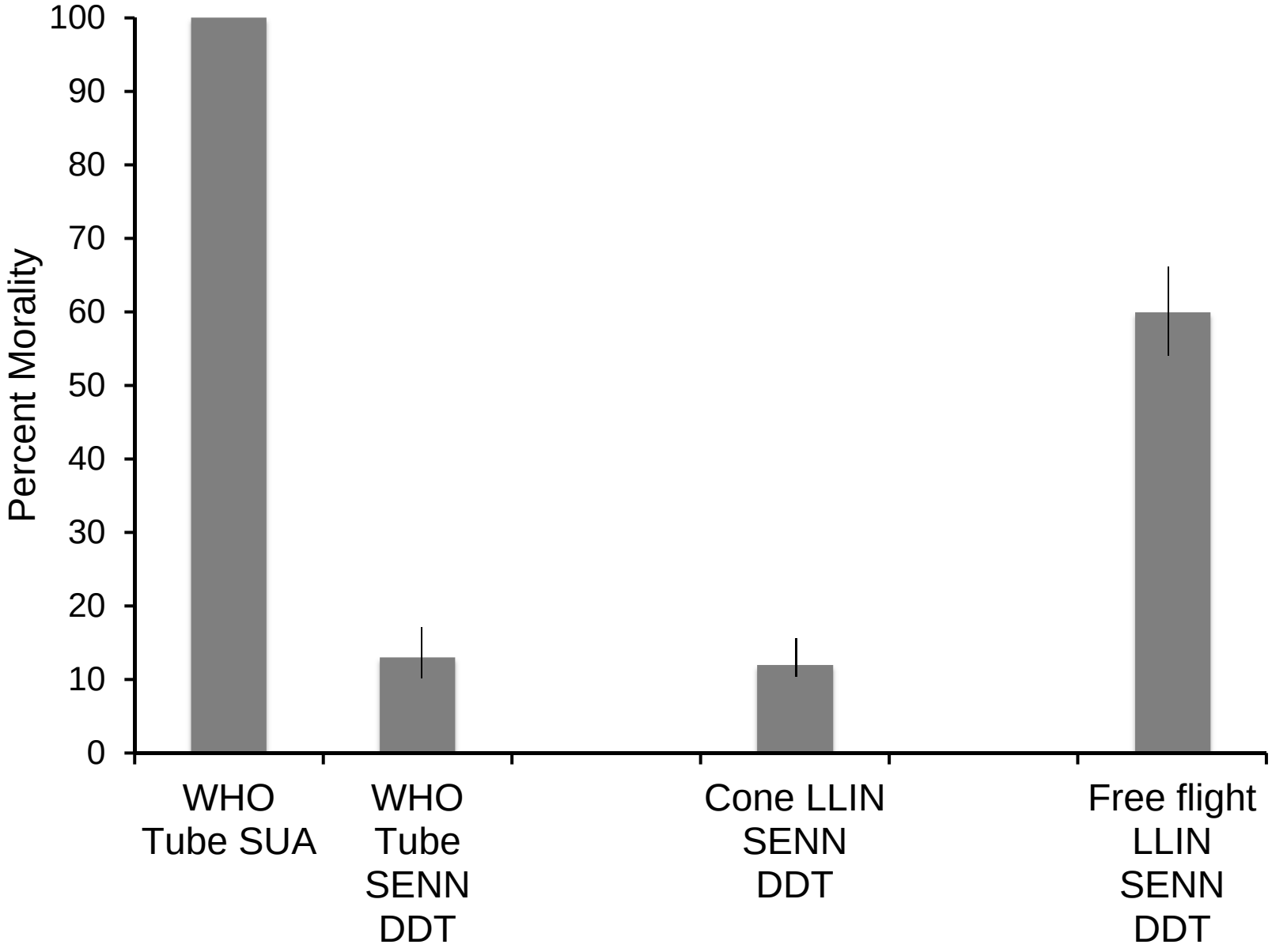
The point of monitoring should be to understand what products or actives can be used, rather than what can't be used due to loss of susceptibility in the target insects.

If the assays or markers correlate poorly with operationally relevant outcomes, they provide little insight.

Demonstrating the impact of resistance and subsequent value of IRM strategies requires appropriate methods for characterizing resistance.

IRM needs better assays…..

Comparison of mortality from standard WHO tests vs free ranging mosquitoes searching around a host protected under LLIN for 1 hour (SENN-DDT, *An. arabiensis*)



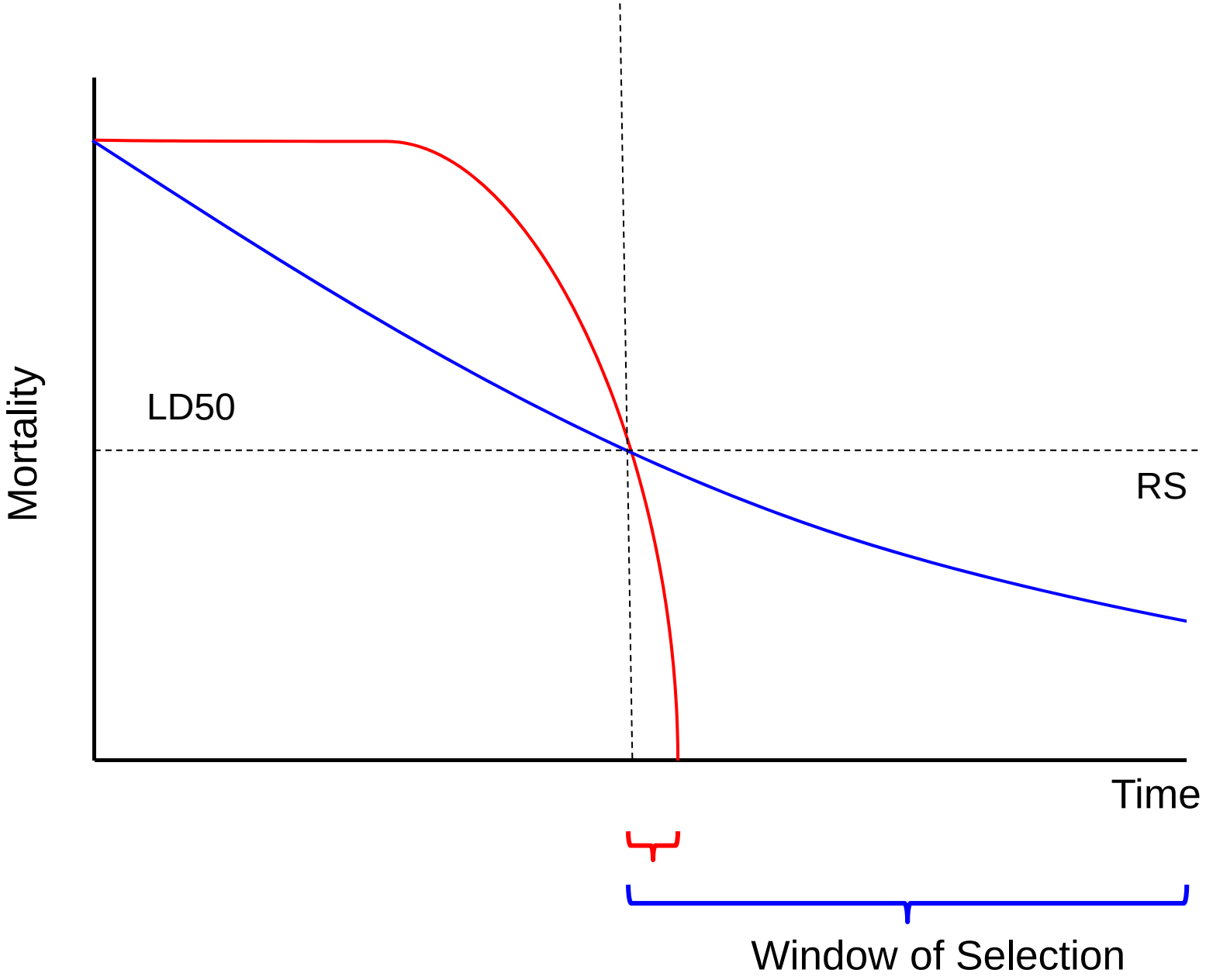
(iii) New Tools

Current TPPs emphasize persistent products with long decay half-lives.

This feature could maximize selection for resistance.

Defining outcome-based TPPs (where the outcomes are reducing transmission and slowing selection for resistance) could encourage development of a broader range of vector control products.

Hypothetical insecticide persistence curves. Slow decay could allow survival of resistant heterozygotes creating large ‘window of selection’

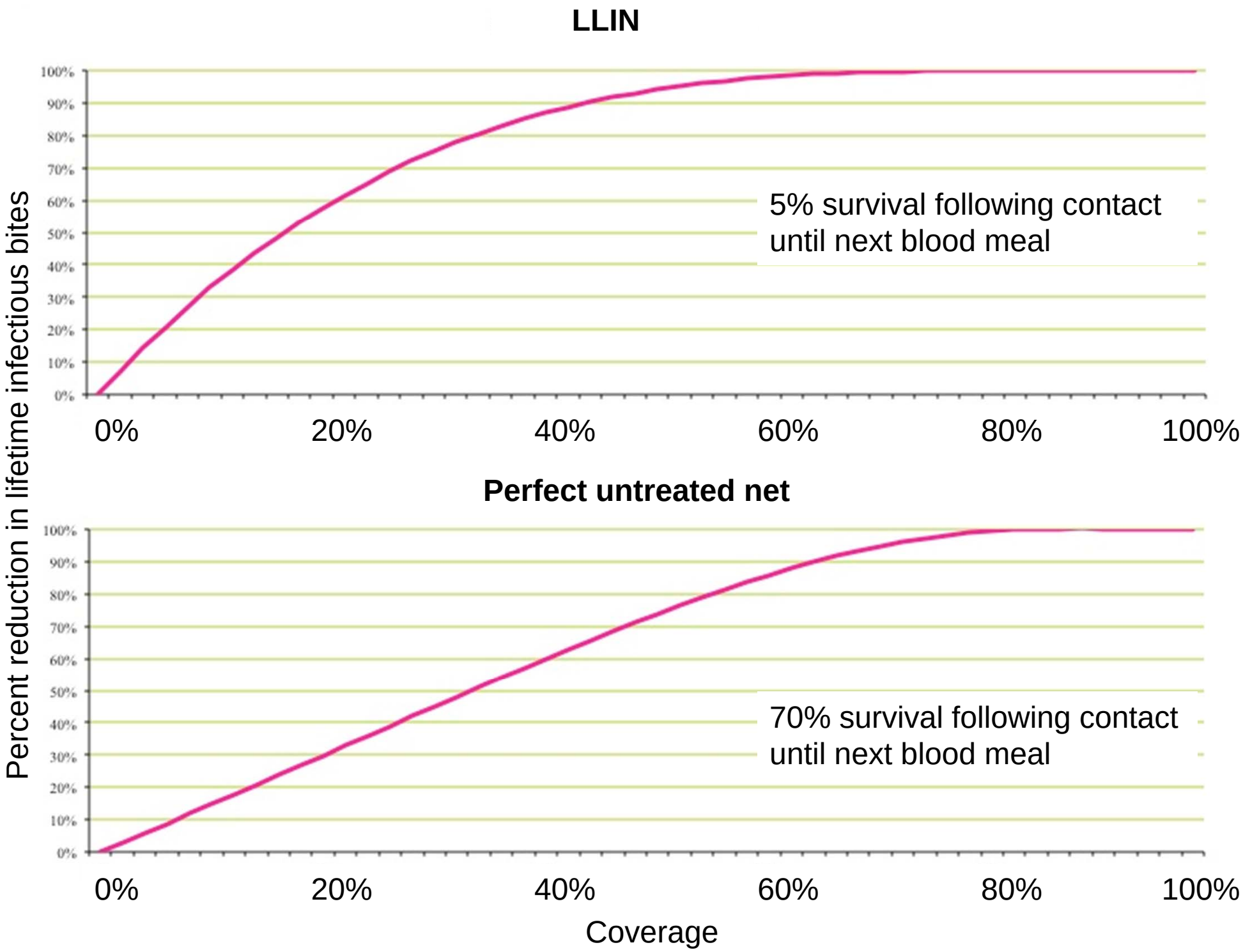


(iv) Knowledge

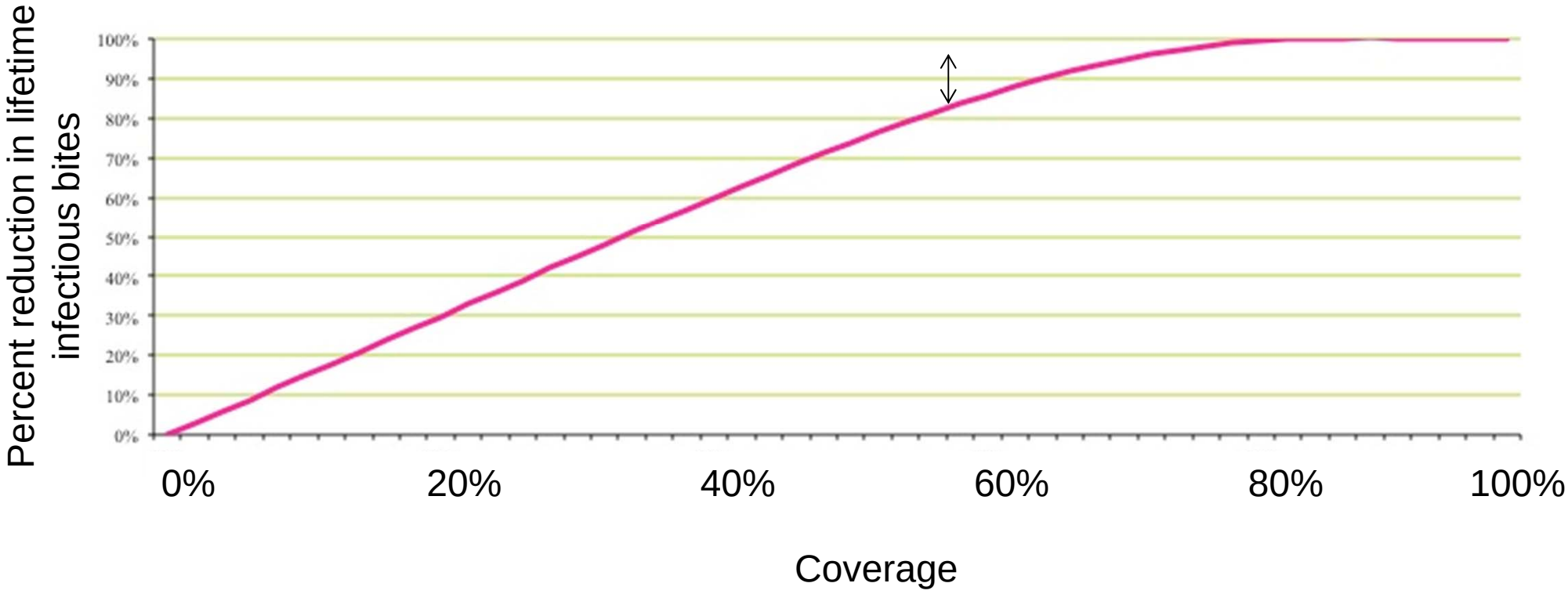
Numerous studies in agriculture demonstrate evolution of insecticide resistance with direct links to crop loss.

However, the relationship between vector resistance and disease epidemiology can be complex (probably more so than in agriculture).

Development of effective IRM strategies requires better understanding of these relationships.


LLIN
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
5% survival following contact
until next blood meal
0%
20%
40%
60%
80%
100%
Perfect untreated net
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
70% survival following contact
until next blood meal
0%
20%
40%
60%
80%
100%
Percent reduction in lifetime infectious bites
Coverage

Effect size of resistance might appear very small in some contexts



(v) Enabling mechanisms

Need to consider susceptibility as a ‘public good’ and transition to value-based rather than cost-based products and approaches.

Achieving this requires a change in national and international policy and development of appropriate regulation……

Conclusions (key insights from Agriculture)

(i) Best approach to resistance management is IPM (so need IVM).

(ii) If monitoring is to be useful, it needs to tell us something about functional significance of resistance. Current resistance monitoring tells us little.

(iii) Agriculture manages resistance in part through a product pipeline. Need a better pipeline to support development of new products (with 'Outcome-based' TPPs).

(iv) Need better understanding of functional significance of resistance. Also need better understanding of impact of potential IRM strategies (very little evidence base for current prescriptions).

(v) Need to accept susceptibility as a public good and consider 'value' and not simply 'cost'