Modeling recovery in risk assessment and management

Getting the purpose, limits, uses and partnerships established before you start!

Paul Jepson

Oregon State University

IPPC
integrated plant protection center

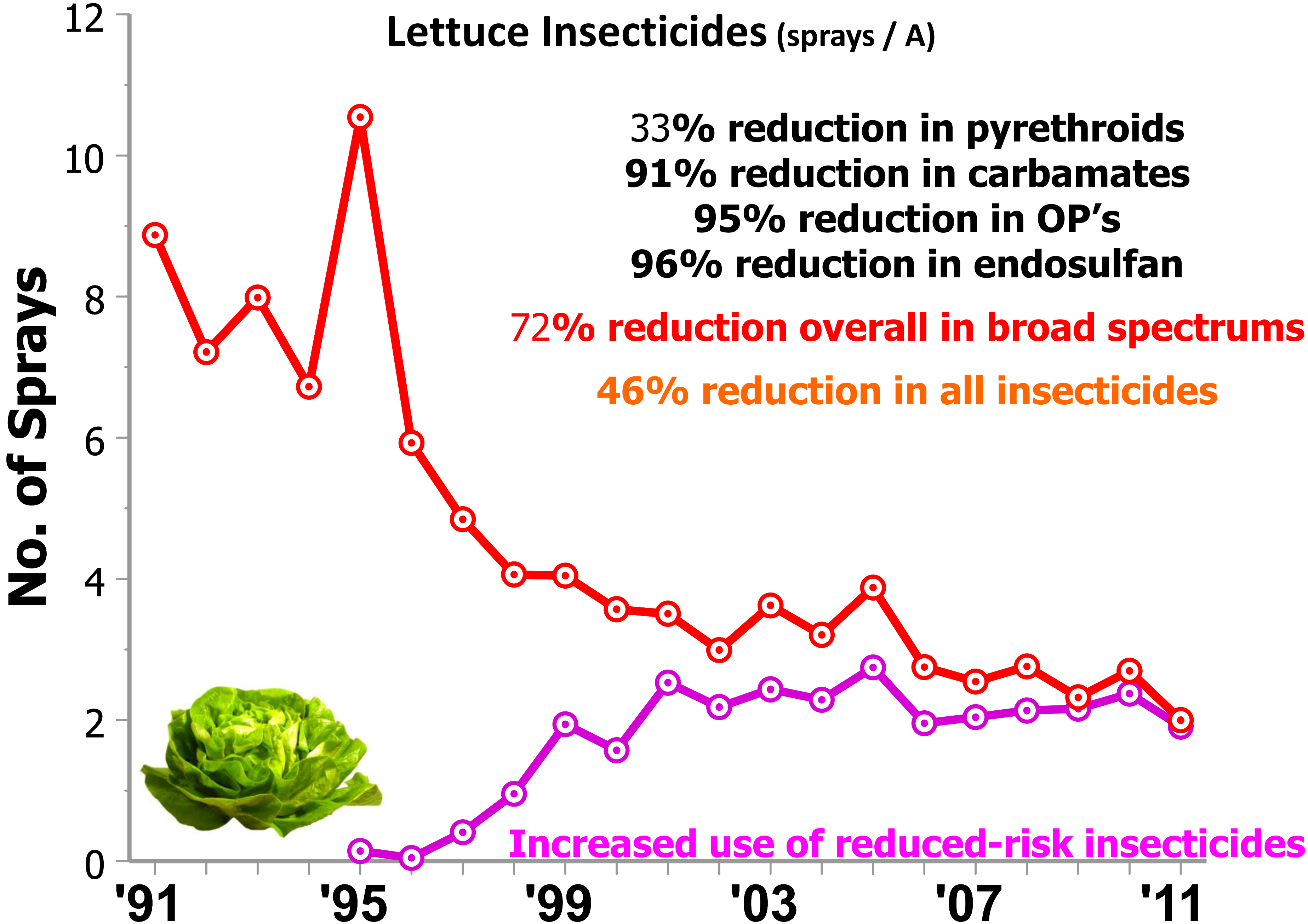
OSU

Pesticide risk reduction through effective regulation, education and engagement with farmers

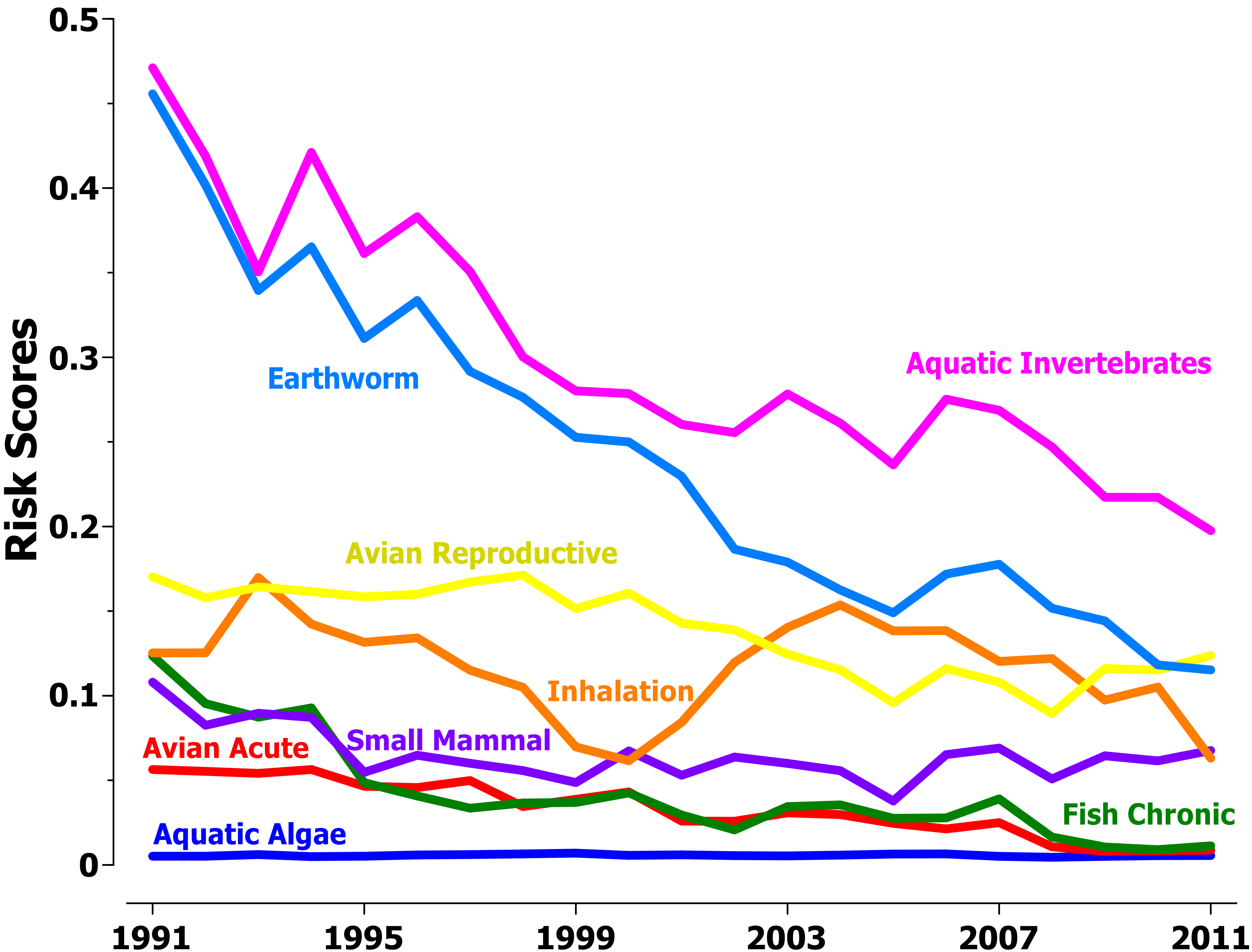
- **Can farmers, supported by effective regulation, education, monitoring and feedback limit pesticide risks over time?**

Pesticide Use in Arizona Lettuce: Understanding and Reducing Risk

Paul Jepson, Michael Guzy, Peter Ellsworth, Al Fournier, Wayne Dixon, John Palumbo



APMC Pesticide Use Database, Lettuce 3/12


0.5
0.4
0.3
0.2
0.1
0
Risk Scores
1991
1995
1999
2003
2007
2011
Earthworm
Aquatic Invertebrates
Avian Reproductive
Inhalation
Small Mammal
Avian Acute
Fish Chronic
Aquatic Algae

IPM and pesticide stewardship partnerships to limit pesticides in Oregon surface waters

Paul Jepson, Mary Halbleib,

Oregon State University

Kevin Masterson,
Oregon Department of Environmental Quality

+ about 4,000 farmers

OSU

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Pesticide Stewardship Partnerships (PSPs)

Key Steps in Oregon Partnership Projects

Monitor for current use pesticides in surface waters from drift & runoff

↓

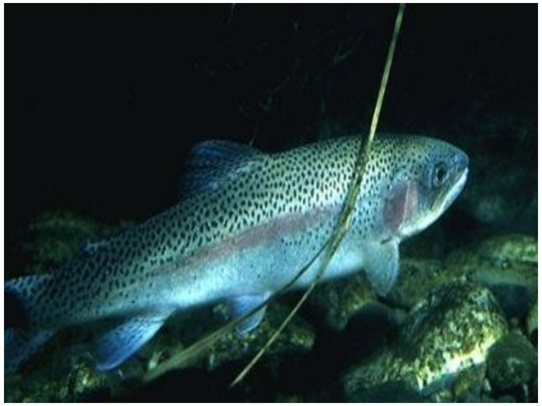
Identify streams with elevated pesticide concentrations or **high # of detections**

↓

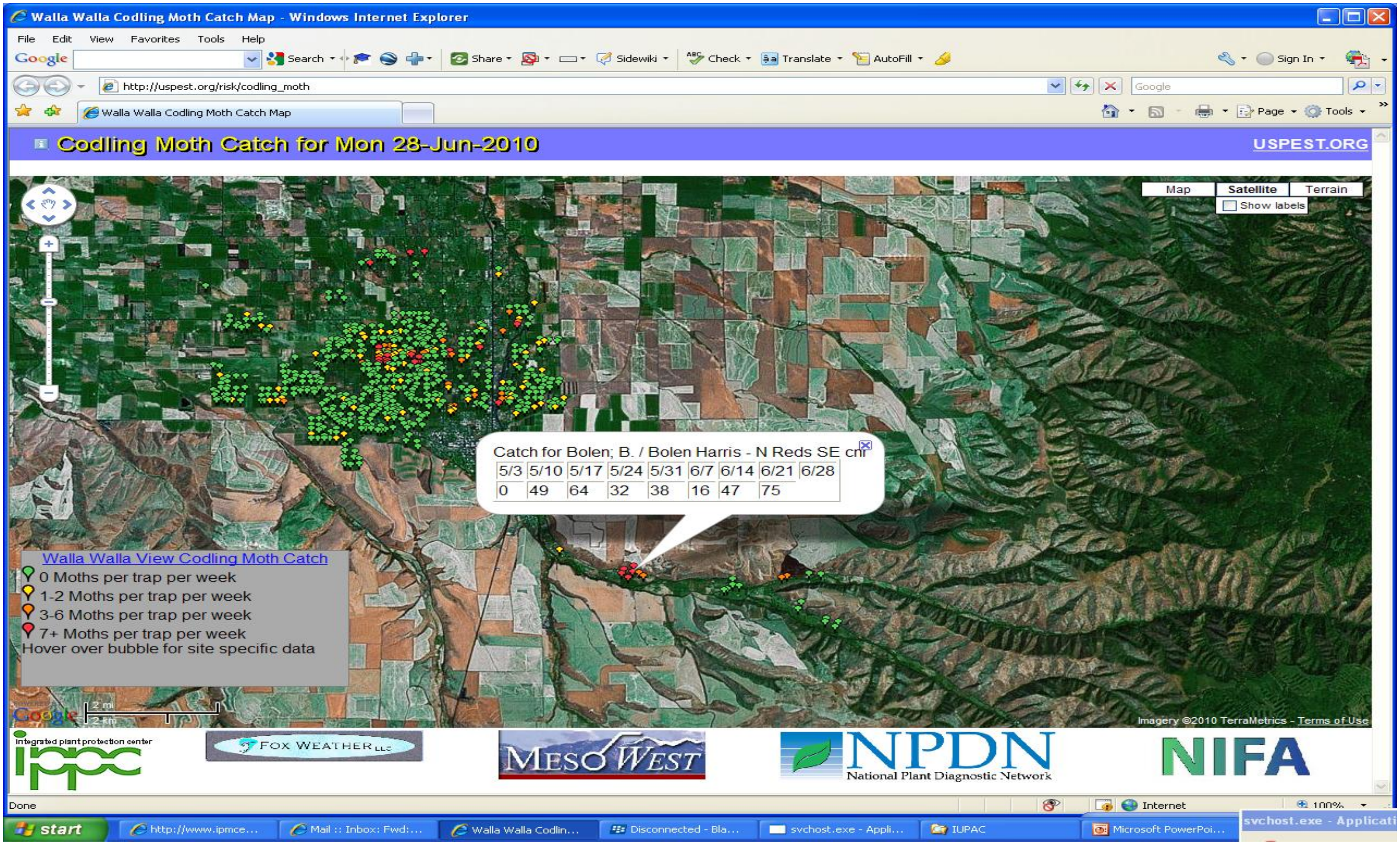
Collaborate to implement voluntary management practices

↓

Follow-up monitoring to determine improvements over time

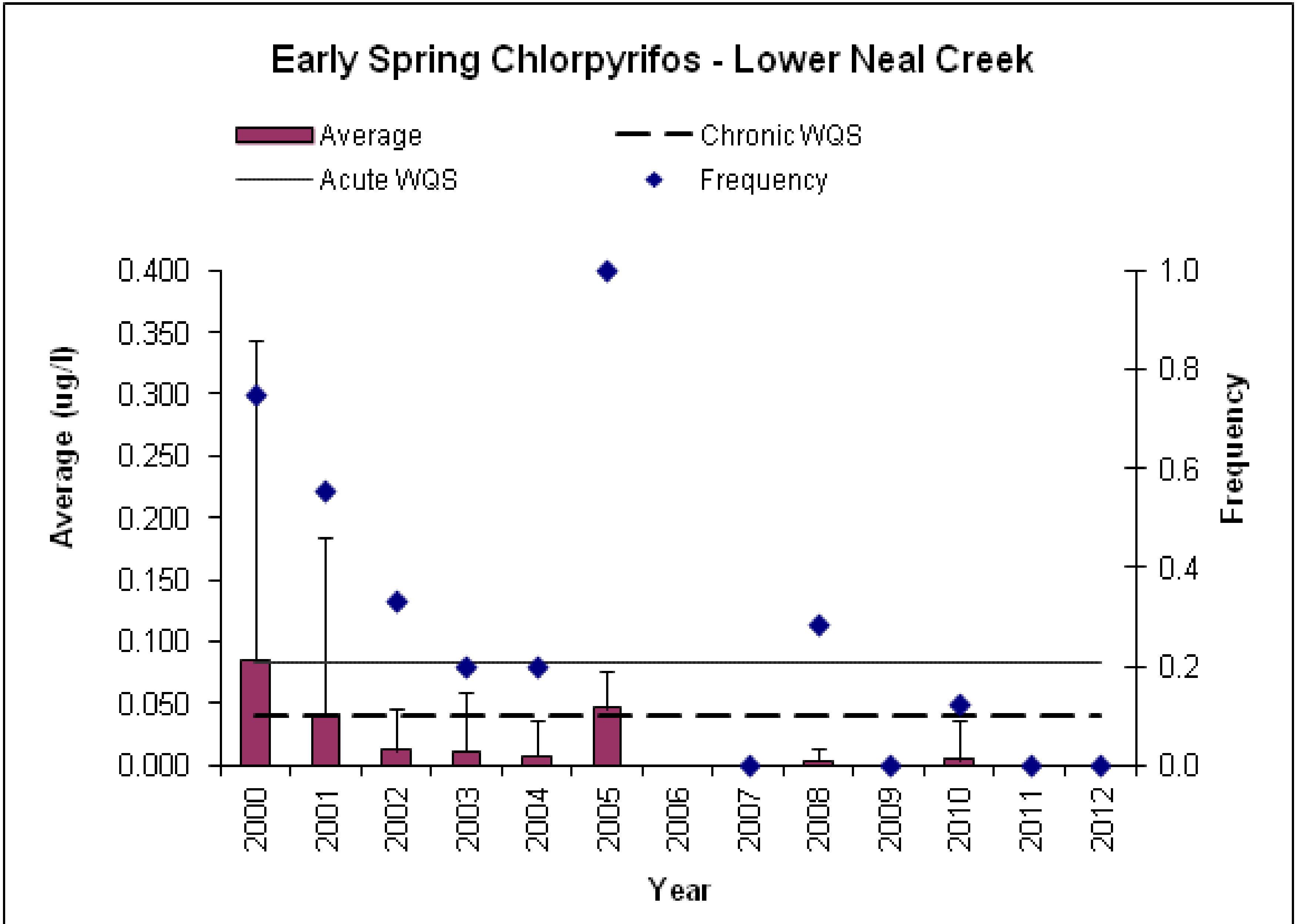


Real-time monitoring of pest epidemics, coupled to pest phenology models, to focus on field-by-field decision making



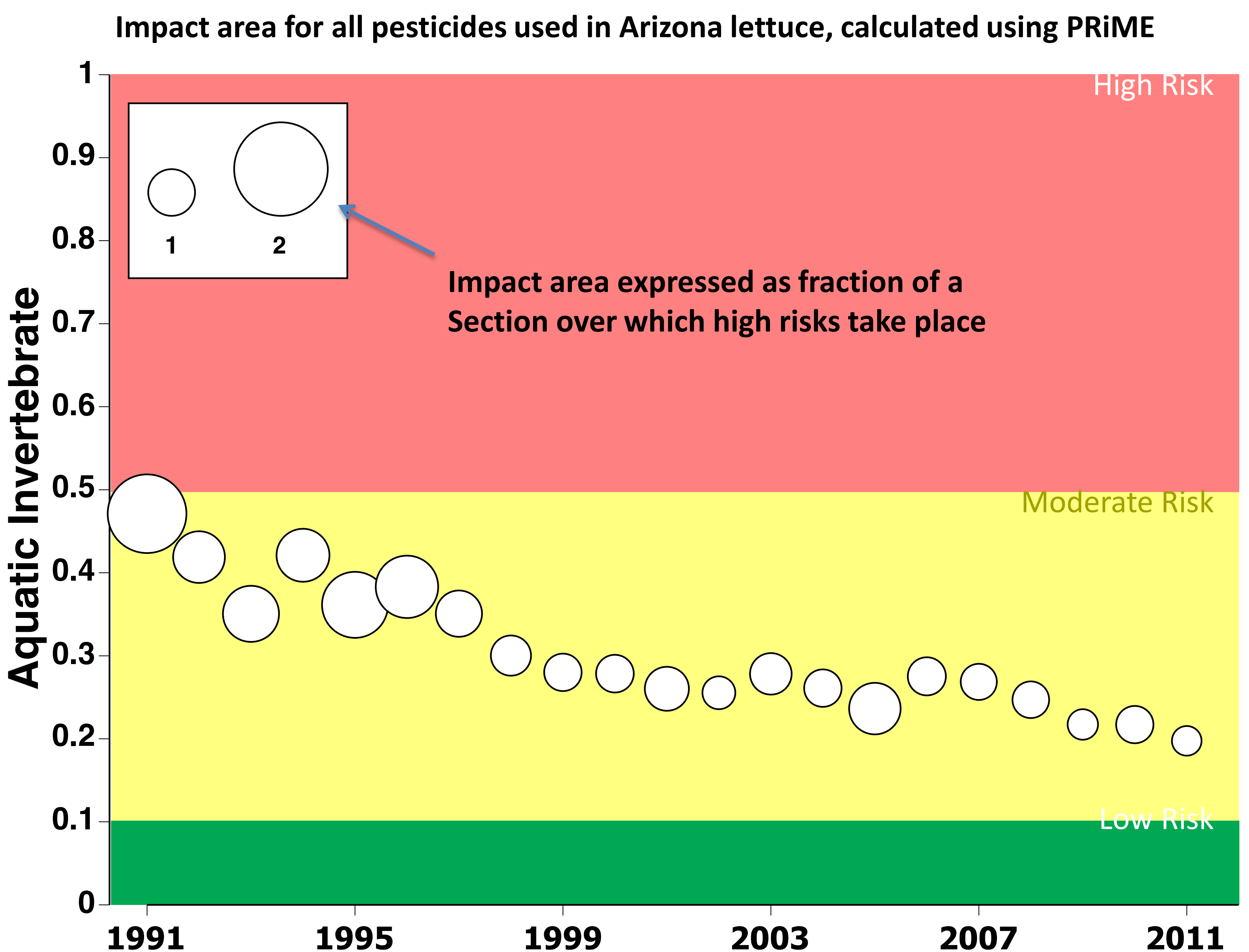
http://uspest.org/risk/codling_moth

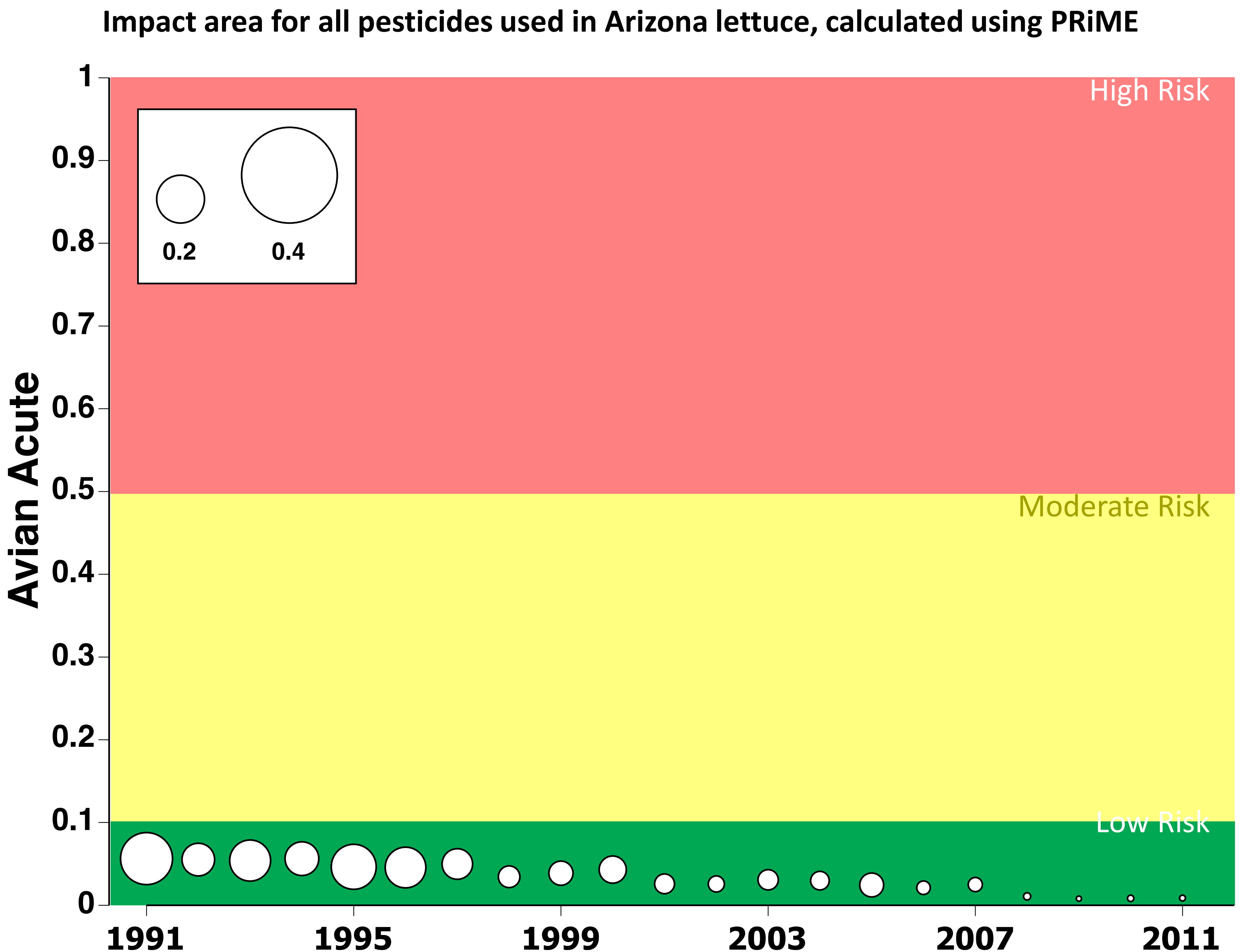
PSP Results Hood River, Oregon



Pesticide risk reduction (PRR)

- Can farmers, supported by effective regulation, education, monitoring and feedback, limit pesticide risks to aquatic and terrestrial wildlife over time?
- **Can farmers limit the area of pesticide impact over time, by adopting both IPM and PRR, supported by research and education?**


Impact area for all pesticides used in Arizona lettuce, calculated using PRiME
Aquatic Invertebrate
High Risk
Moderate Risk
Low Risk
1
2
Impact area expressed as fraction of a Section over which high risks take place
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1991
1995
1999
2003
2007
2011


Impact area for all pesticides used in Arizona lettuce, calculated using PRiME
Avian Acute
High Risk
Moderate Risk
Low Risk
0.2
0.4
1
0.9
0.8
0.7
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0.5
0.4
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1991
1995
1999
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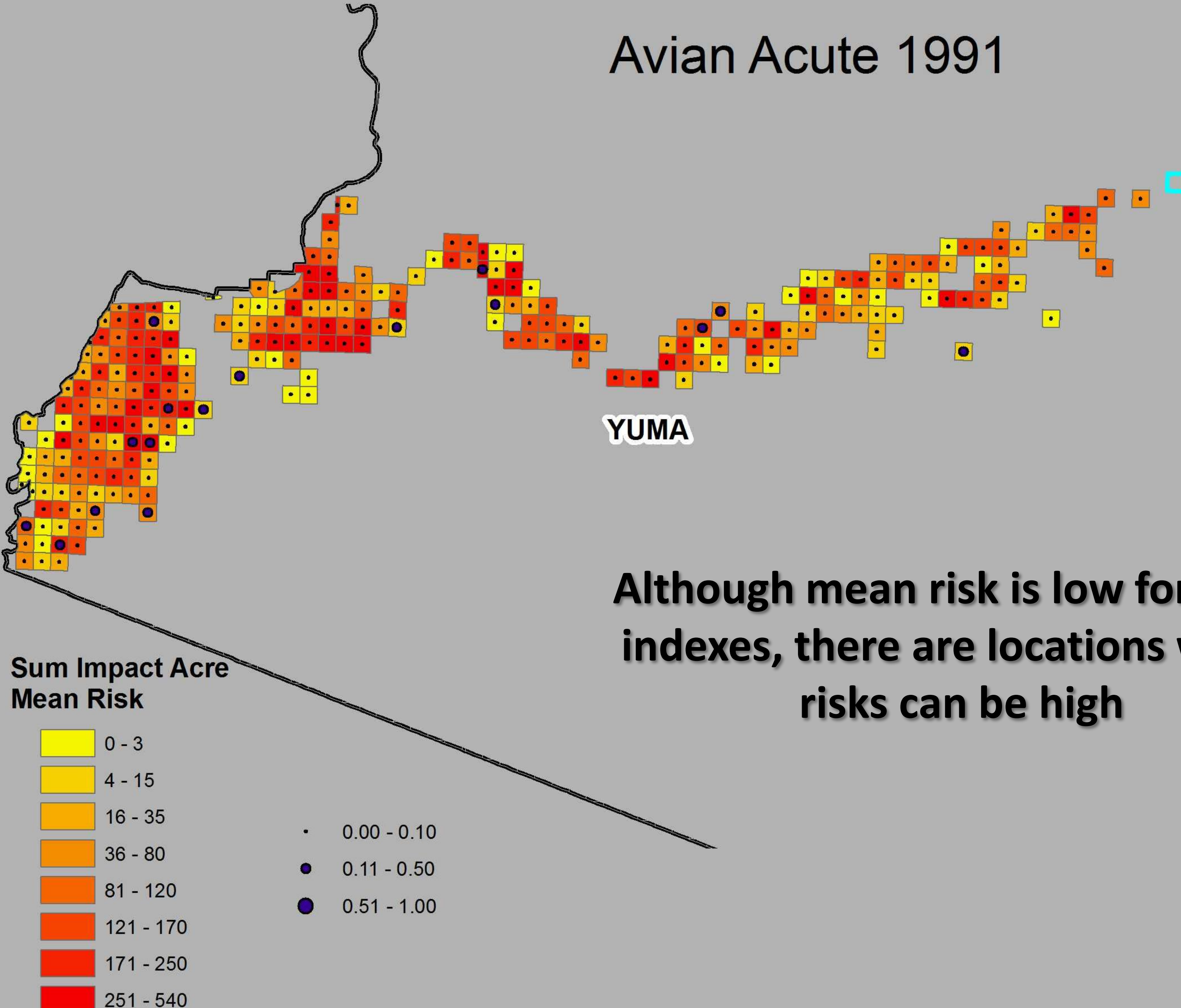
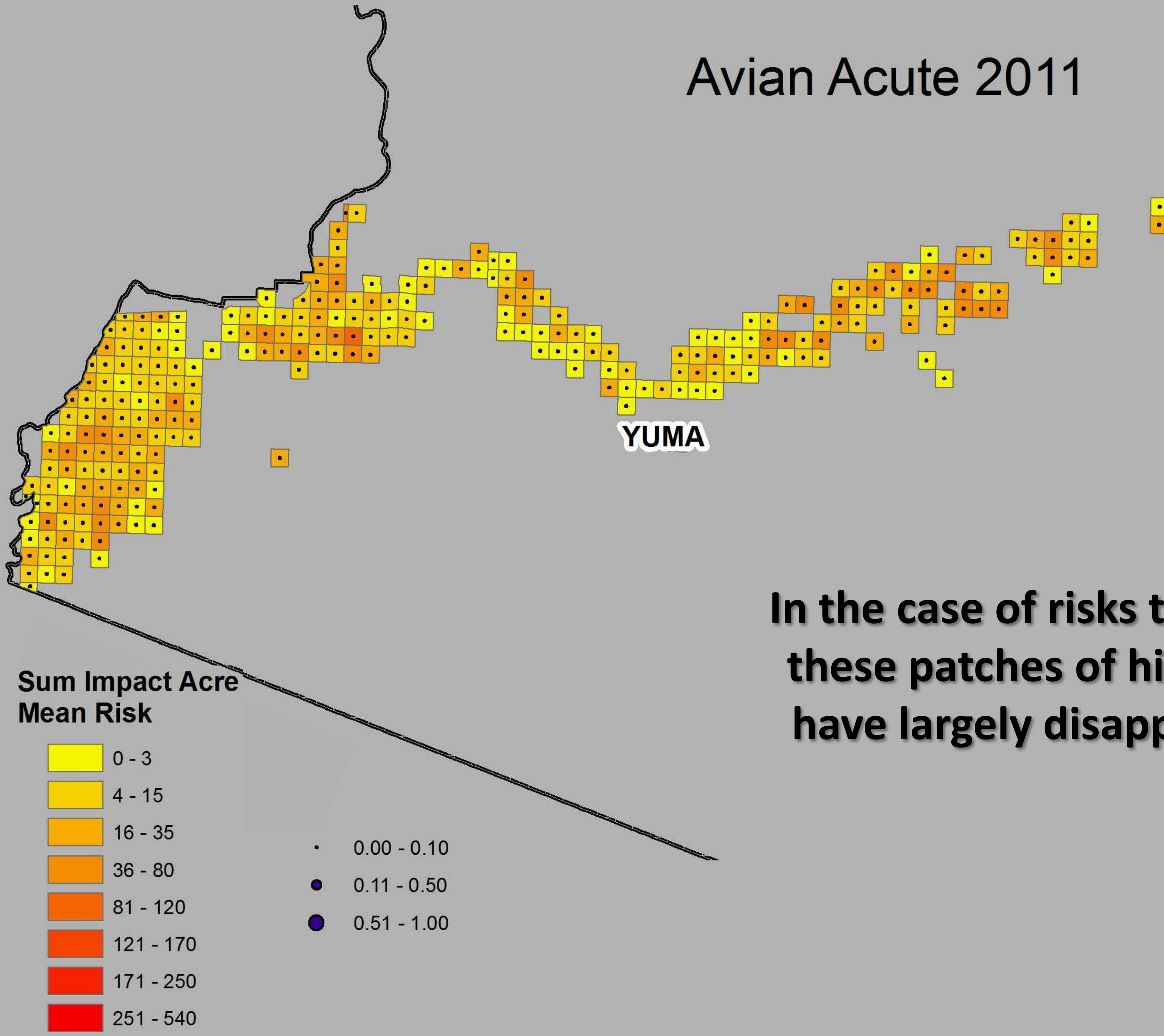
Avian Acute 1991



Although mean risk is low for some indexes, there are locations where risks can be high

Avian Acute 2011



In the case of risks to birds, these patches of high risk have largely disappeared

Pesticide risk reduction (PRR)

- Can farmers, supported by effective regulation, education, monitoring and feedback, limit pesticide risks to aquatic and terrestrial wildlife over time?
- Can farmers limit the area of pesticide impact over time, by adopting both IPM, supported by research and education?
- **Is impact area a relevant focus for risk assessment that acknowledges recovery?**

Mechanisms underlying adverse pesticide impacts at different scales

MICRO SCALE

f (exposure, susceptibility)

MESO SCALE

f (chemical persistence, life history, habitat requirements, dispersal rate, diet range)

MACRO SCALE

f (spatio-temporal patterns of chemical use, life history, trophic interactions, habitat characteristics and layout)

(Actual scaling, organism and habitat dependent)

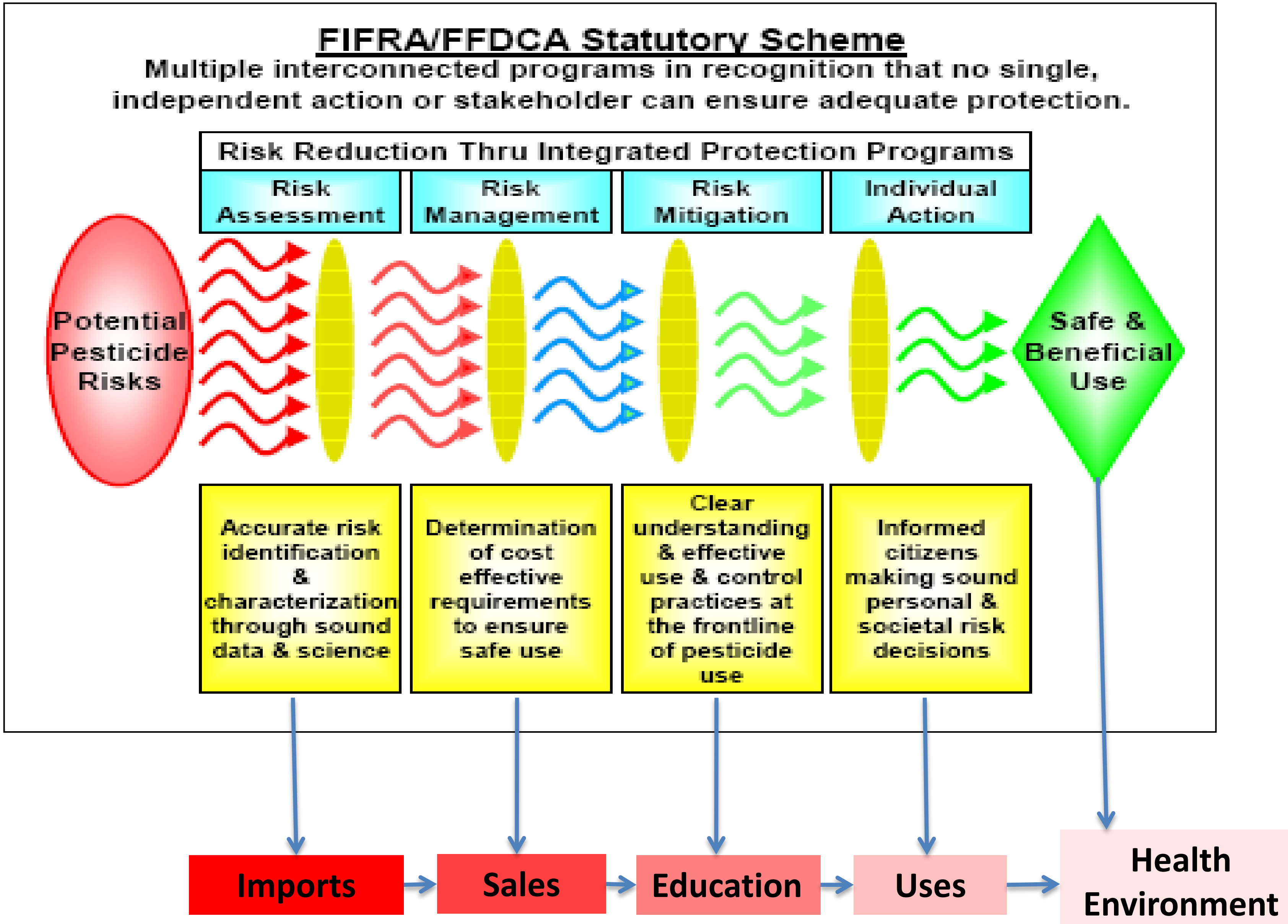
Jepson, P.C. (1989) "The temporal and spatial dynamics of pesticide side-effects on non-target invertebrates". In: *Pesticides and non-target invertebrates* (Ed. P.C. Jepson), pp 95-128. Intercept, Wimbourne.

Jepson, P.C. (2007) Ecotoxicology and IPM, In: Kogan, M., Jepson, P.C. (Eds) *Perspectives in Ecological Theory and Integrated Pest Management*, pp 522-551 Cambridge University Press, UK. 570pp

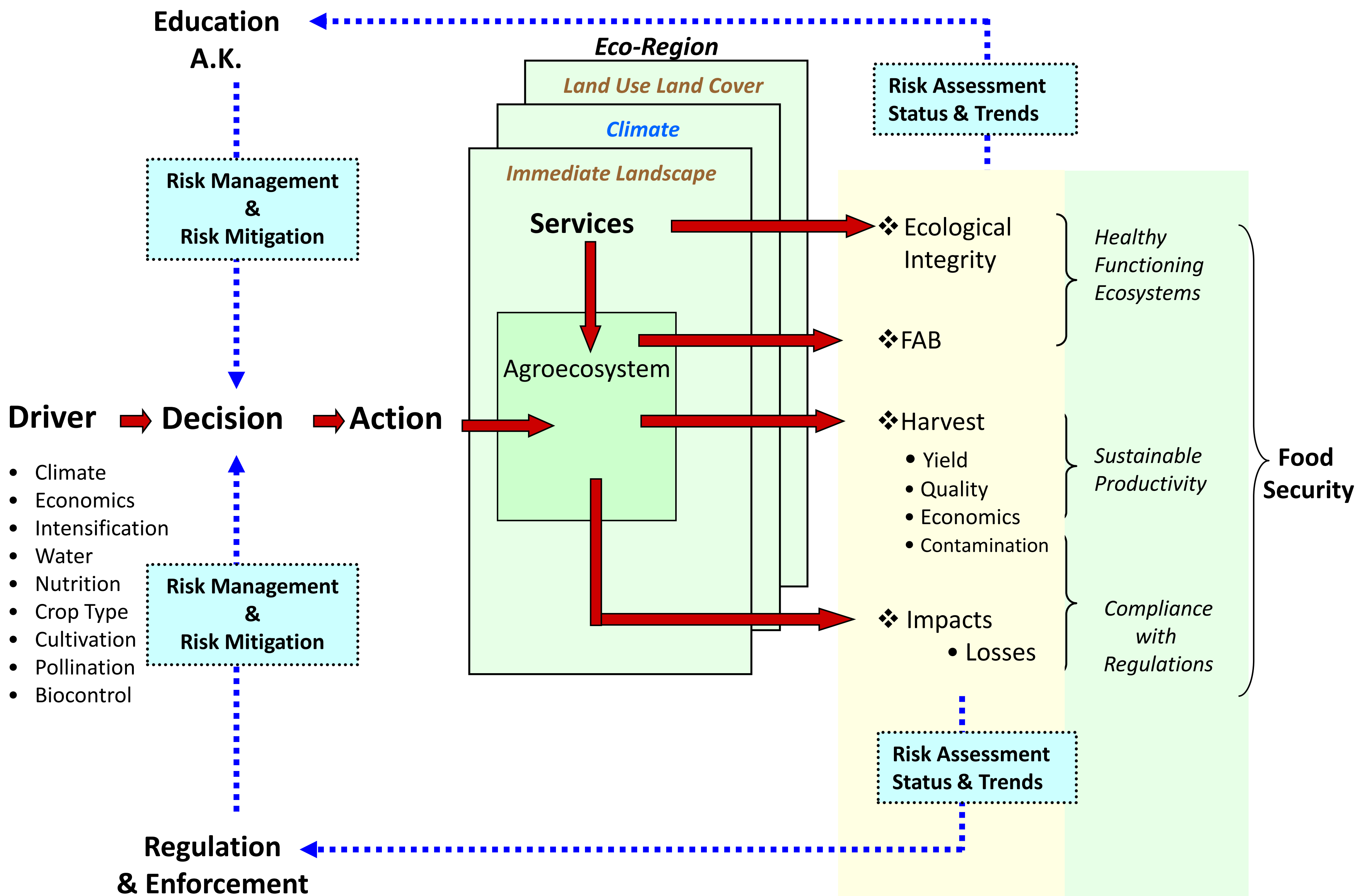
What have we learned, regulators in the room?

1. Having a quantifiable outcome is important, so that you know if you are achieving your goal
2. Engaging with farmers removes uncertainties in the risk assessment process associated with climate, soil, crops, habitats, biota at risk, exposed habitats, scaling of the system, between year variability
3. Success is built upon monitoring and measurement, and analysis of current status and trends in the real world

Is there a lesson here for the implementation of risk assessment processes that acknowledge recovery?



THE END USER, AND EDUCATION MUST BE CONSIDERED TO ACHIEVE THE GOALS OF EFFECTIVE REGULATION



Jepson et al, 2014: Phil. Trans Royal Society, in press

How much of this are you seeking to cover, and can suites of models be designed that support the part of the process that you are seeking to influence?

Are you seeking to model recovery in all potential landscapes?

Are you seeking to identify areas and uses where there is a high risk of recovery failing to occur?

If such locations are identified, what are you going to do about it? Rely on models and eliminate uses in specific locations, or identify locations and develop partnerships that mitigate or eliminate the risk??

Why is recovery a useful thing to estimate in a regulatory context?

- Allows measurement of the <u>duration</u> of an ecological effect
- Places emphasis upon population level effect, rather than individual impacts, in the period immediately following exposure
- Acknowledges need to consider surrounding landscape, and the overall meta-population
- Link with adverse secondary impacts, including resurgence and secondary pest outbreaks, that do not occur when recovery is rapid
- Failure to recover provides a mechanism that underlies local extinction or extirpation
- Enables appropriate scale to be established for experiments that attempt to measure ecological risk (i.e. avoidance of edge effects and between-treatment interference)

Definitions of ecological recovery following depletion or extirpation by pesticides

(Maltby et al. (2001) In: Baird & Burton SETAC Press)

- No days affected population growth rate lags behind unaffected population (Kareiva *et al.*, ‘96)
- Time to recover to 80% of control (Jepson & Thacker, ’93)
- Time to approach SE of pre-treatment populations (Jepson & Thacker, ’90)
- Return of perturbed system to window of natural variability (Weins, ’96)
- Time when N., relative to control, reach 90% of pre-treatment numbers (Sherratt *et al.*, ’99)

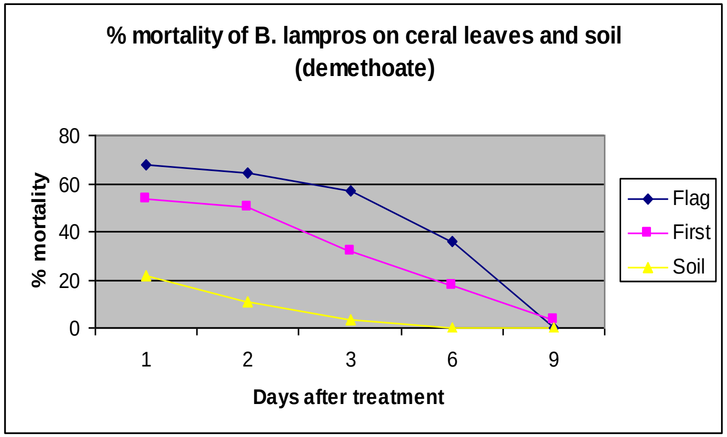
Do you already have the data that you need?

- Can population recovery times be predicted as a function of chemical persistence?
- Can species sensitivity data be used to describe chemical impacts on large taxonomic groups?
- Can chemical fate data be used to predict the point at which ecological recovery can begin?

Estimating time (yrs) for soil invertebrates to initiate recovery following pesticide use

AI	Initial concentration (mg/kg)	HC5, soil invertebrates	Ecotoxicological recovery time	Range ERT from research
Dimethoate	1.1	0.14	0.15	0.13-0.18
Chlorpyrifos	15.1	0.0017	1.1	0.59-7.7
Carbofuran	6.4	0.036	1.2	0.71-3.8
Benomyl	1.3	0.023	3.8	2.8-5.8

van Straalen N.M. & van Rijn, J.P. (1998)
Rev Environ Contam Toxicol 154: 83-141



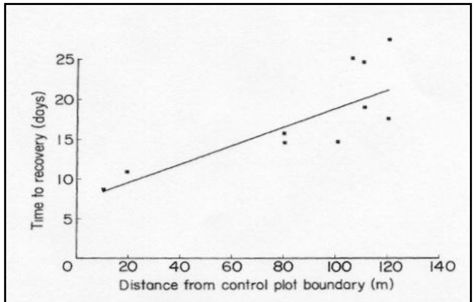
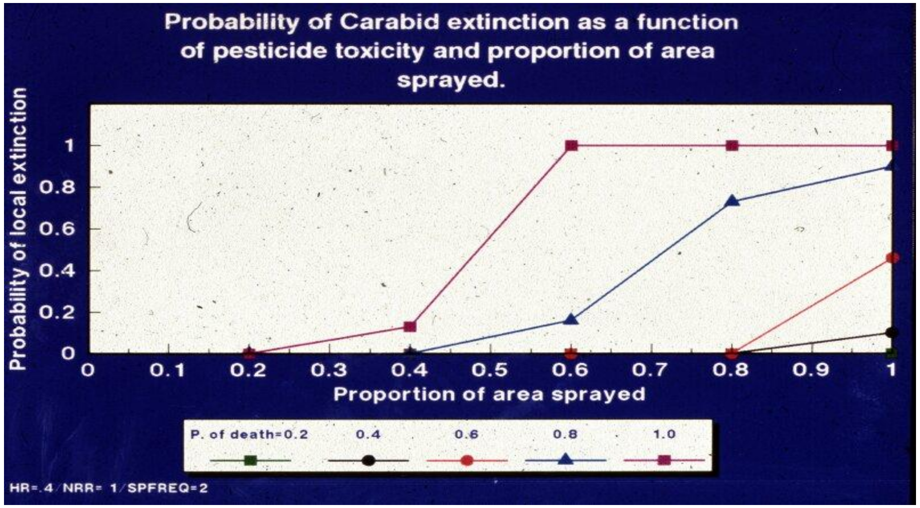


Fig. 5. Time (days) for carabid populations to recover (term defined in text) in the 1987 and 1988 field experiments, expressed against distance of the trapping station from the nearest control-plot boundary (m). Coefficients from linear regression analysis are given in Table 1.

Residue decay followed by re-colonization, with ERT = 10 days



Jepson, Unal, Thacker, Sherratt *et al,* multiple papers

e.g. **Sherratt, T.N., Jepson, P.C.** (1993 *Journal of Applied Ecology*, **30**, 696-705.

Models can incorporate ERT, and be used as a research tool to explore many different scenarios for individual taxa

Is it possible to combine SSD and impact area approaches to identify taxa, crops and agricultural systems at risk, where the application regime is known?

Large impact areas, and high risk will impair recovery

Perspective on factors limiting population recovery/persistence of non-target taxa

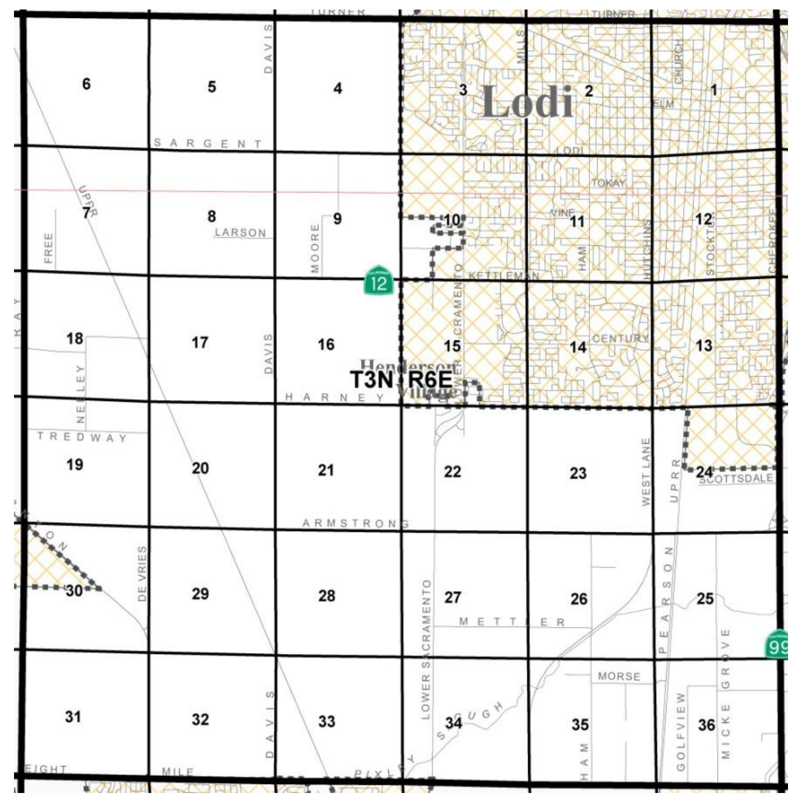
- **Landscape structure and the displacement of fields and refugia**
  - Size, shape and quality of refugia
  - The presence and quality of dispersal routes
  - Spatial configuration of habitat elements
- **Development of understanding of the situations where effects (e.g. local extirpation) will propogate to longer time scales**
  - E.g., from lowest to highest probability
    - Single ‘event’ in a continuous population
    - Low frequency/synchrony events in a continuous population
    - Single event in a patchy population
    - Frequent events in a continuous population
    - Single, large scale event in a continuous population
    - Multiple events in a patchy population
    - Single, large scale event, in a patchy population

Fahrig, L. and K. Freemark. 1995. Landscape-scale effects of toxic events for ecological risk assessment. Pp. 193-208 in: J. Cairns Jr. and B.R. Niederlehner (eds.). *Ecological toxicity testing: scale, complexity, and relevance*. Lewis Publishers.

PRiME beta
Pesticide Risk Mitigation Engine

Landscape Analysis

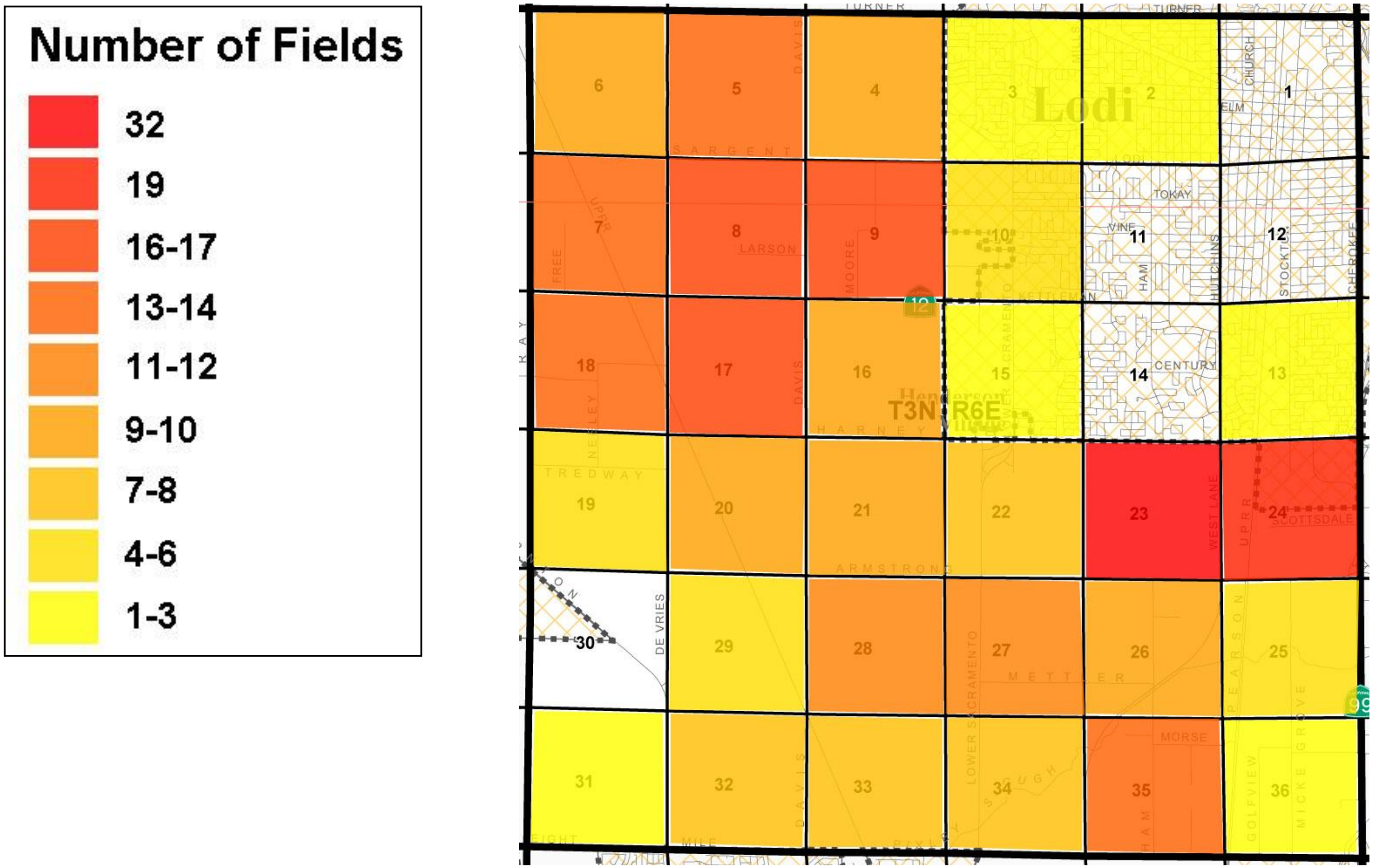
Analyzed all agricultural pesticide applications in 2010 to a 36-square mile block in San Joaquin County, CA.



PRiME beta
Pesticide Risk Mitigation Engine

Landscape Analysis

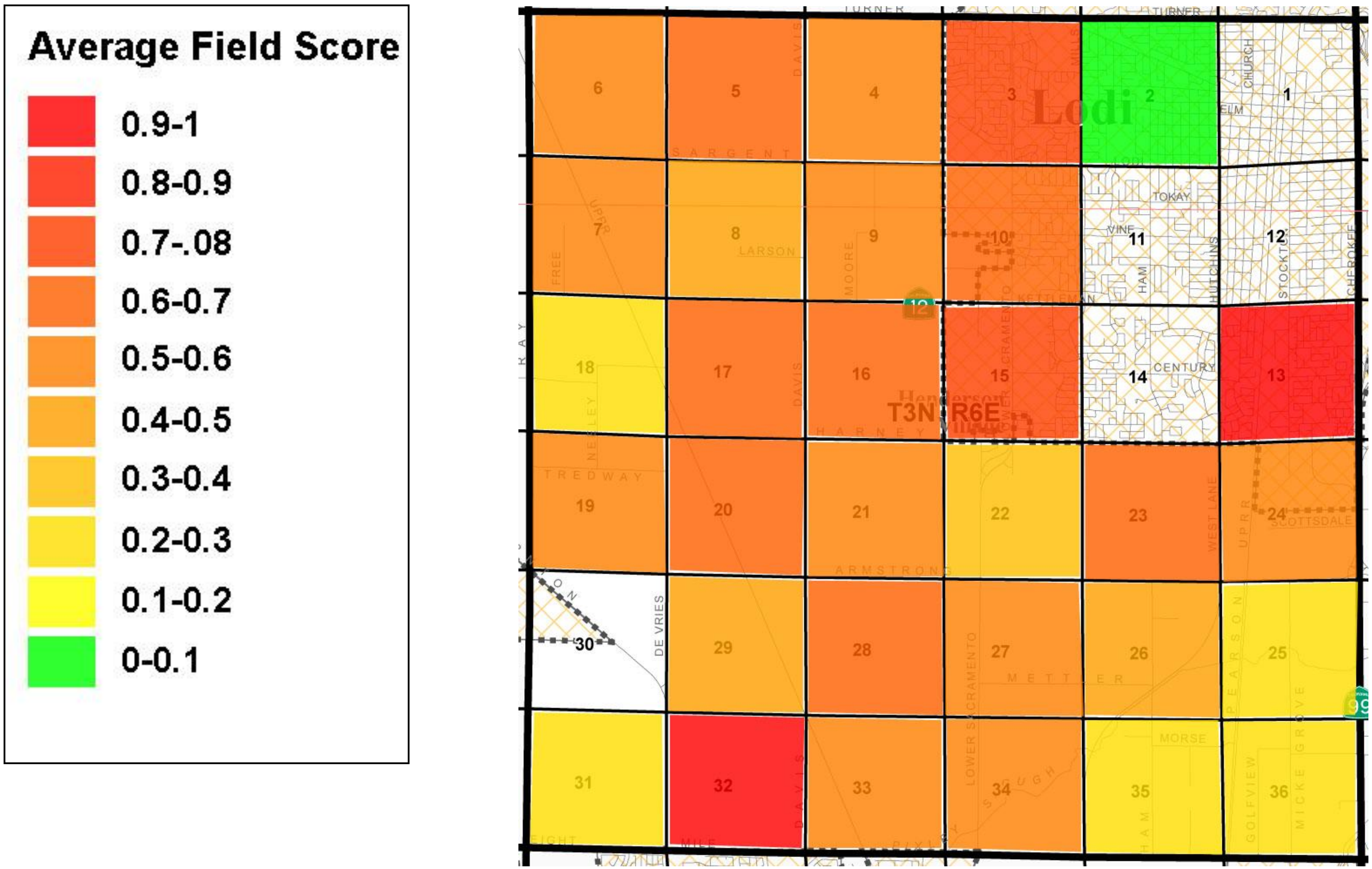
Number of Fields per Section



PRiME[beta]
Pesticide Risk Mitigation Engine

Landscape Analysis

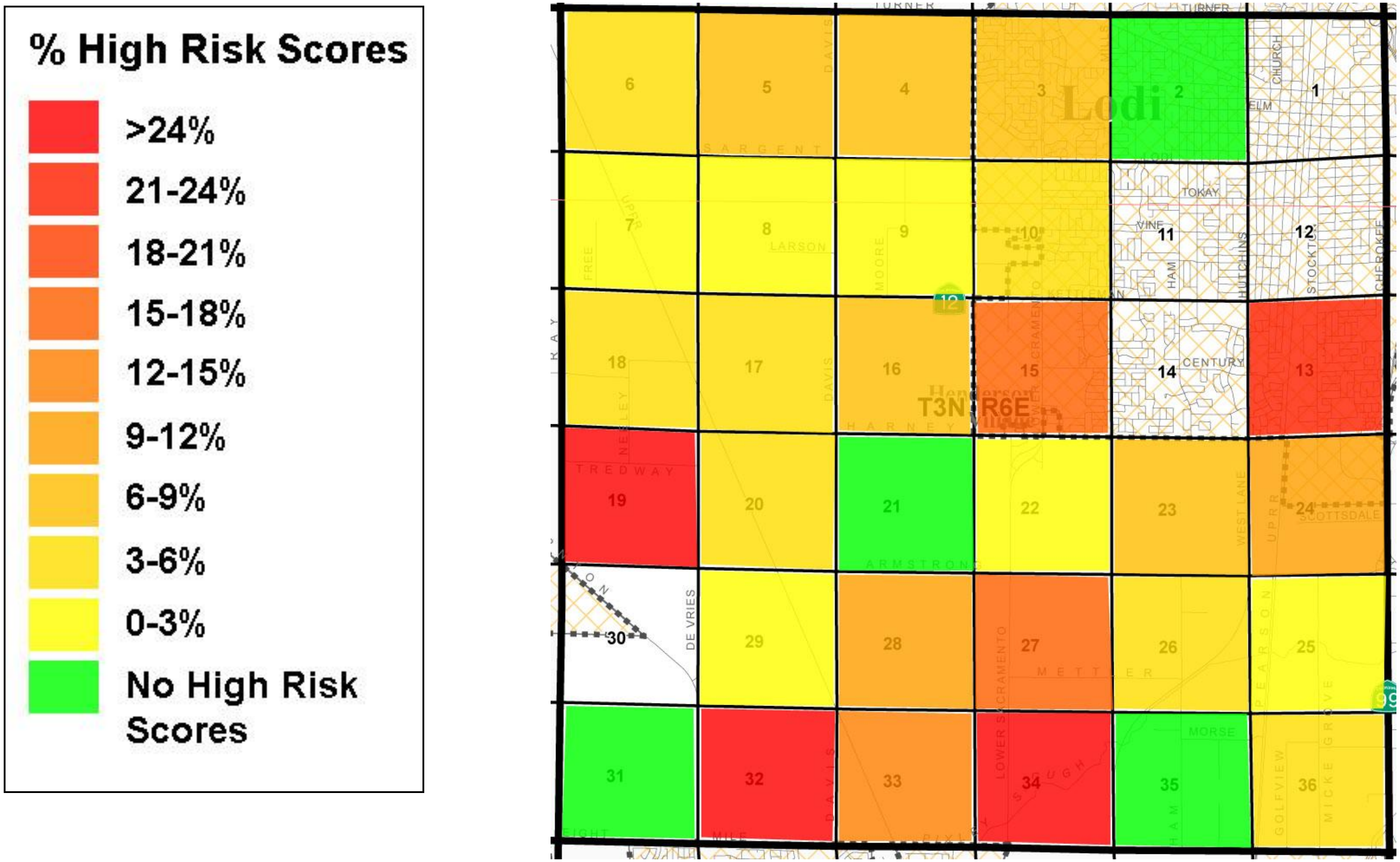
Average PRiME Field Score for Aquatic Invertebrates



PRiME beta
Pesticide Risk Mitigation Engine

Landscape Analysis

Proportion of High Risk Scores for Aquatic Invert.



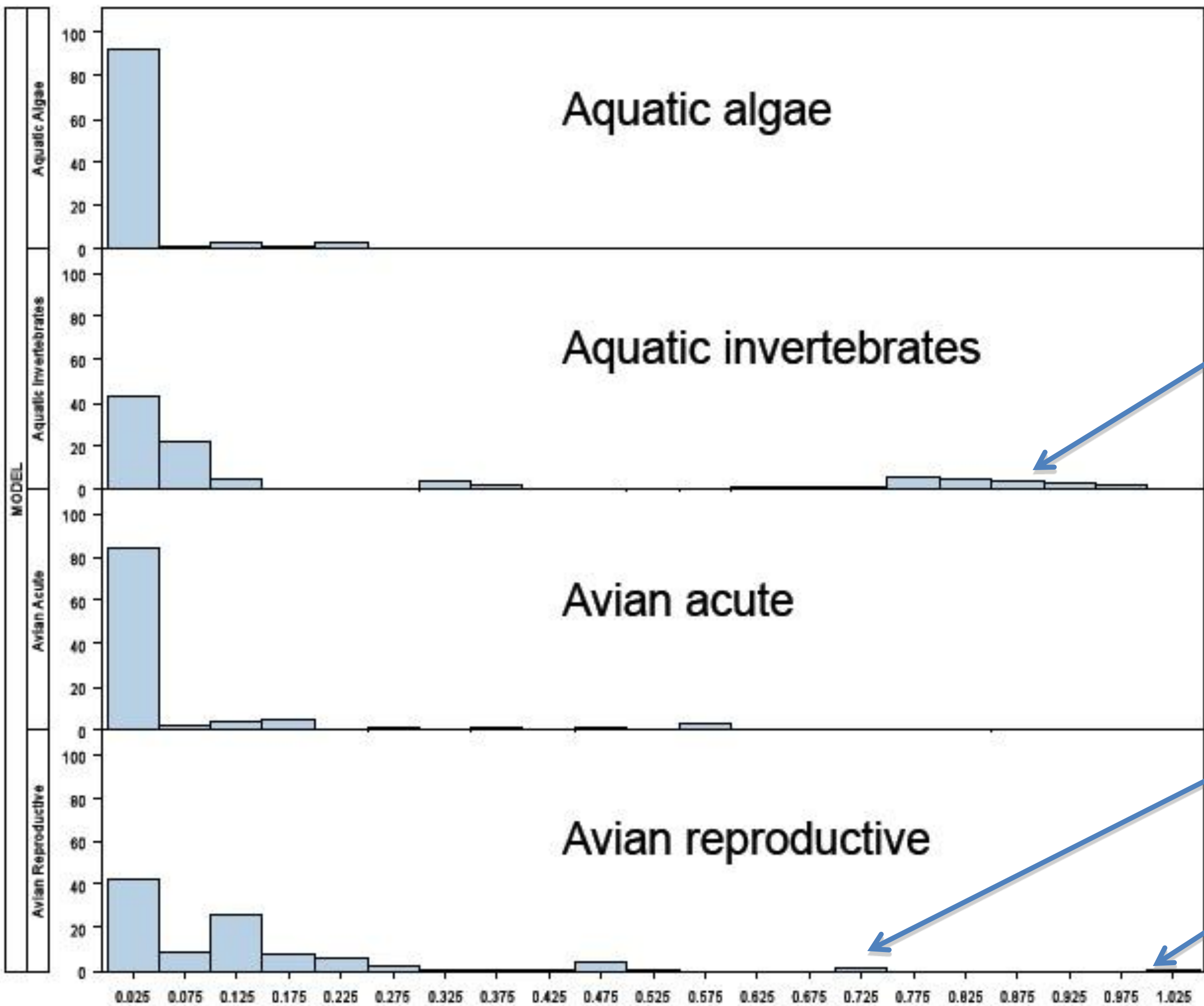
Farmers apply suites of pesticides: how do risks of whole programs compare to risks associated with individual sprays?

Example dataset: vegetables, June applications, 2010

- 1,226 applications to vegetables incl: green, wax and Italian beans, broccoli, corn, peas, zucchini
- PRiME indexes calculated for each application and for each farm
- Exploring application of PRiME for development of risk management and mitigation strategies in each commodity, tailored to individual farms (200 growers)

Frequency distribution of risks within each PRiME index

***Independent applications**: takes into account frequency of use as well as toxicity of all materials*

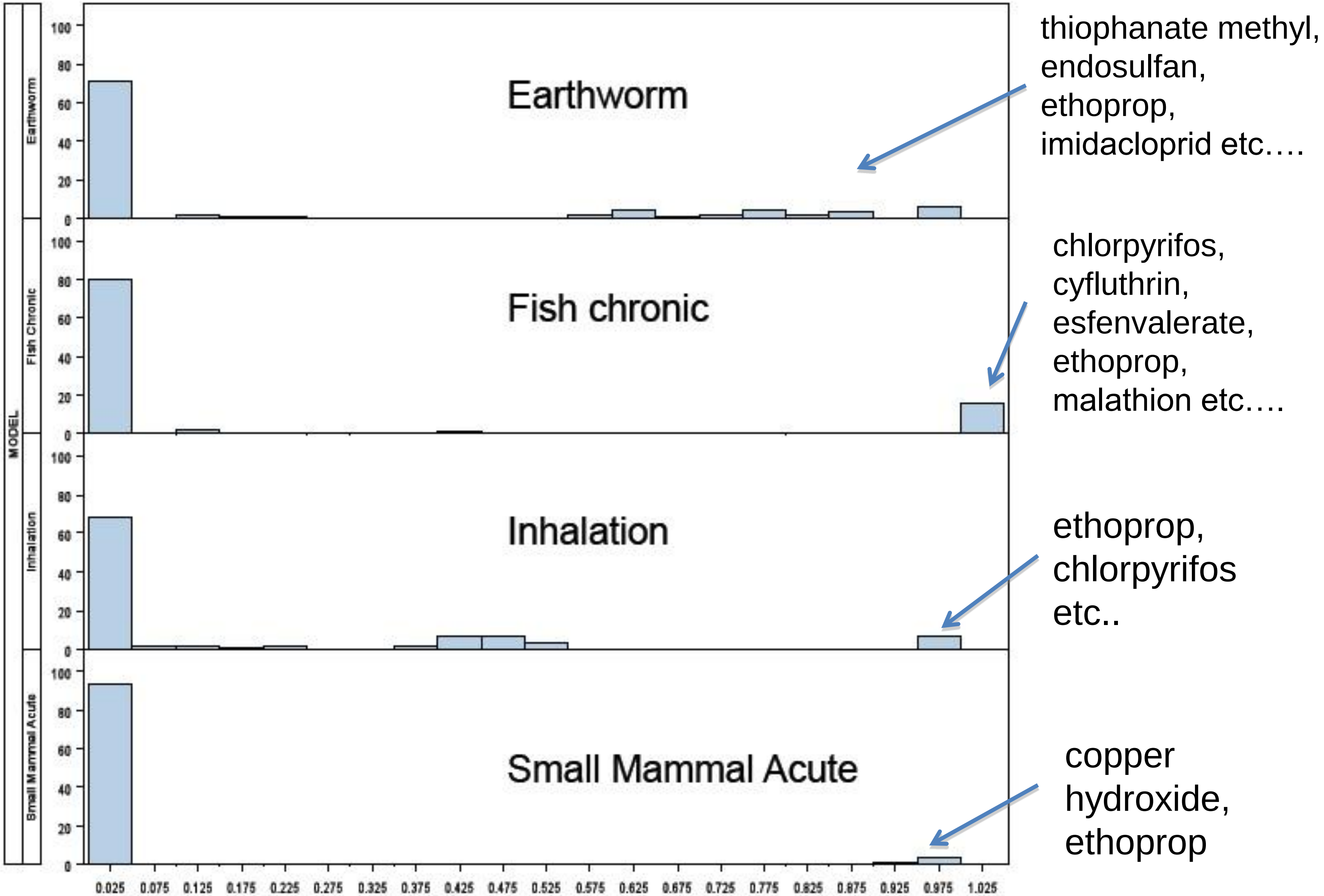


dimethoate, bifenthrin, cyfluthrin, esfenvalerate etc…

pendimethalin

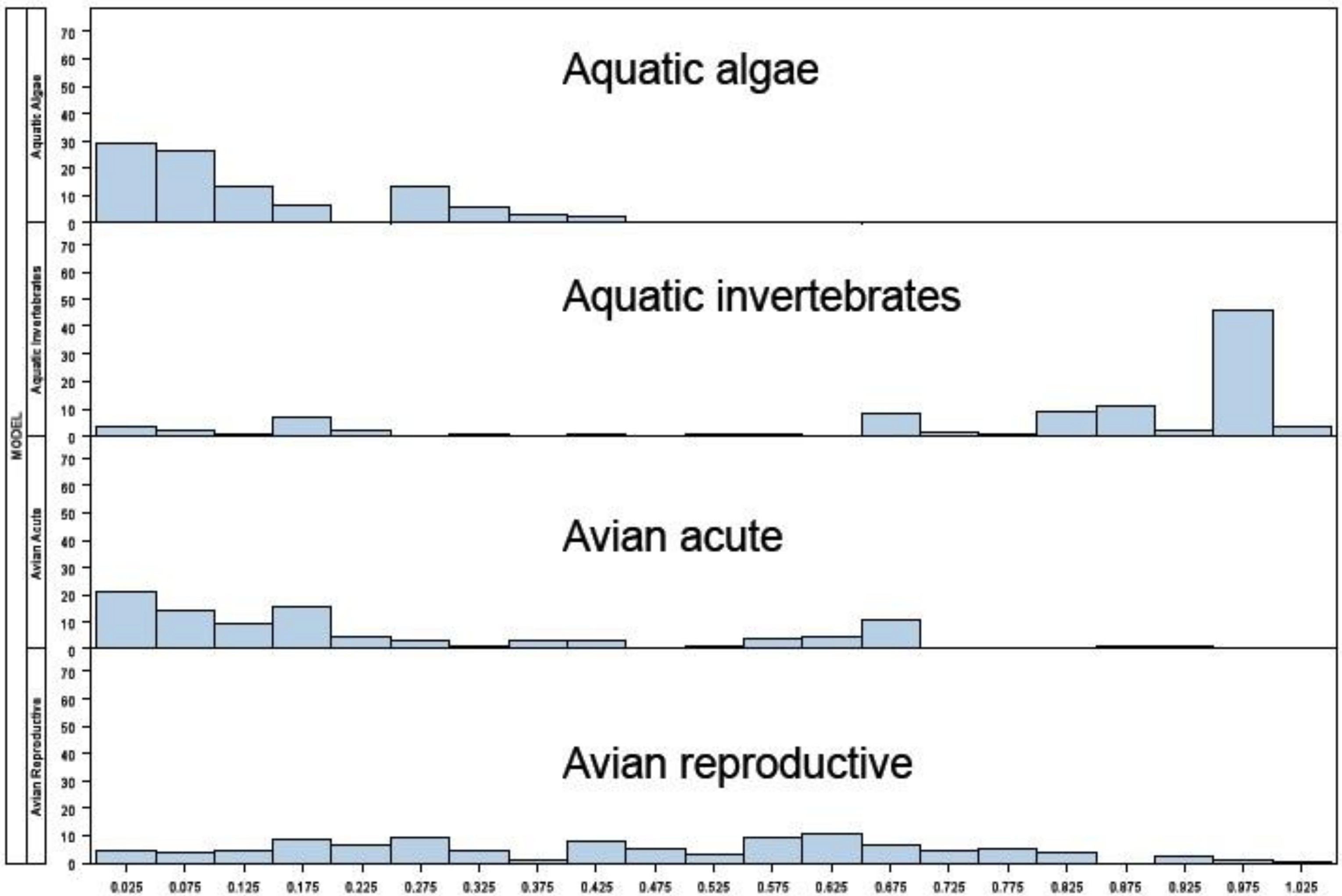
copper hydroxide

Continued:



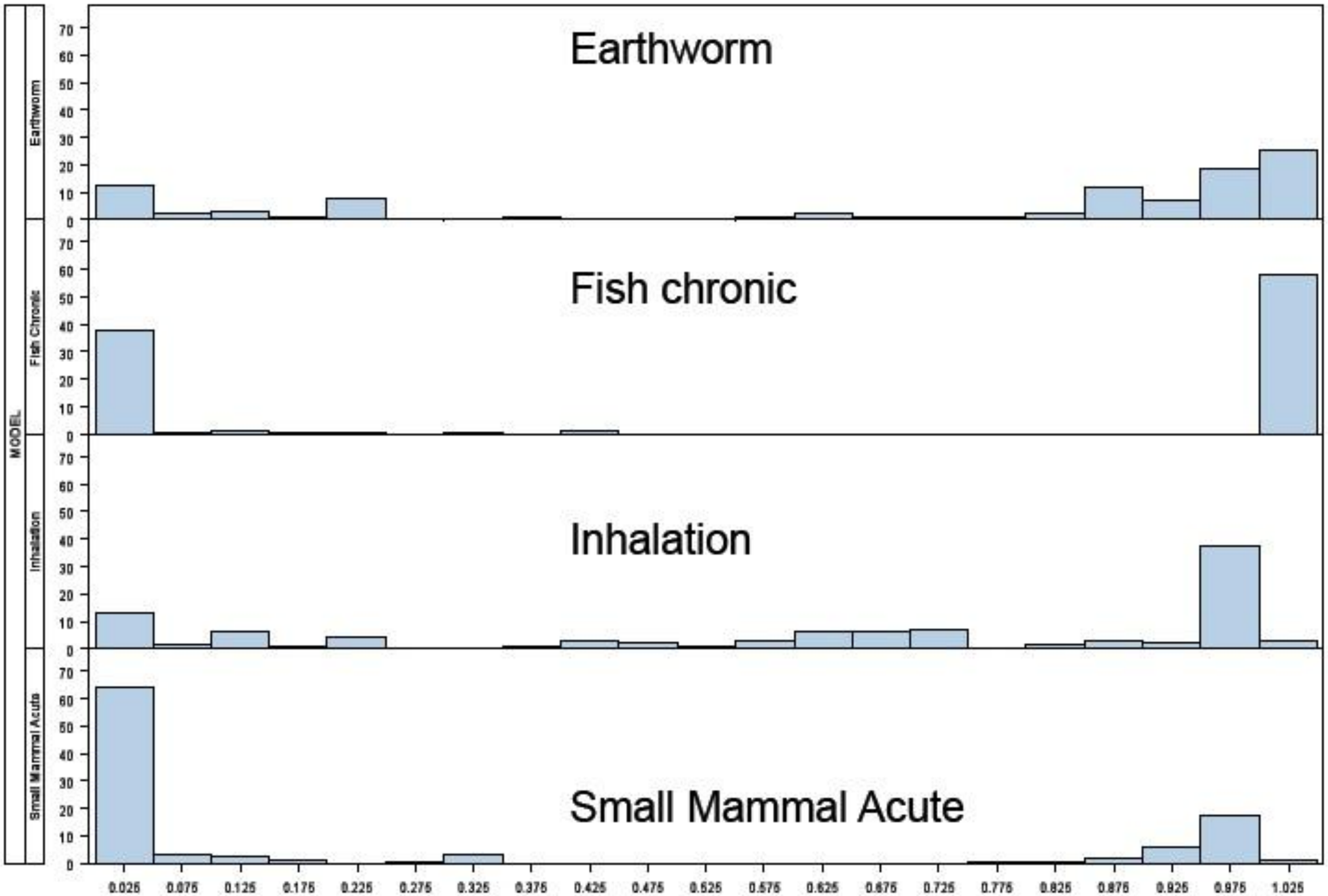
Earthworm
Fish chronic
Inhalation
Small Mammal Acute
MODEL
Earthworm
Fish Chronic
Inhalation
Small Mammal Acute
100
80
60
40
20
0
0.025
0.075
0.125
0.175
0.225
0.275
0.325
0.375
0.425
0.475
0.525
0.575
0.625
0.675
0.725
0.775
0.825
0.875
0.925
0.975
1.025
thiophanate methyl, endosulfan, ethoprop, imidacloprid etc.…
chlorpyrifos, cyfluthrin, esfenvalerate, ethoprop, malathion etc.…
ethoprop, chlorpyrifos etc..
copper hydroxide, ethoprop

Distribution of risks by farm



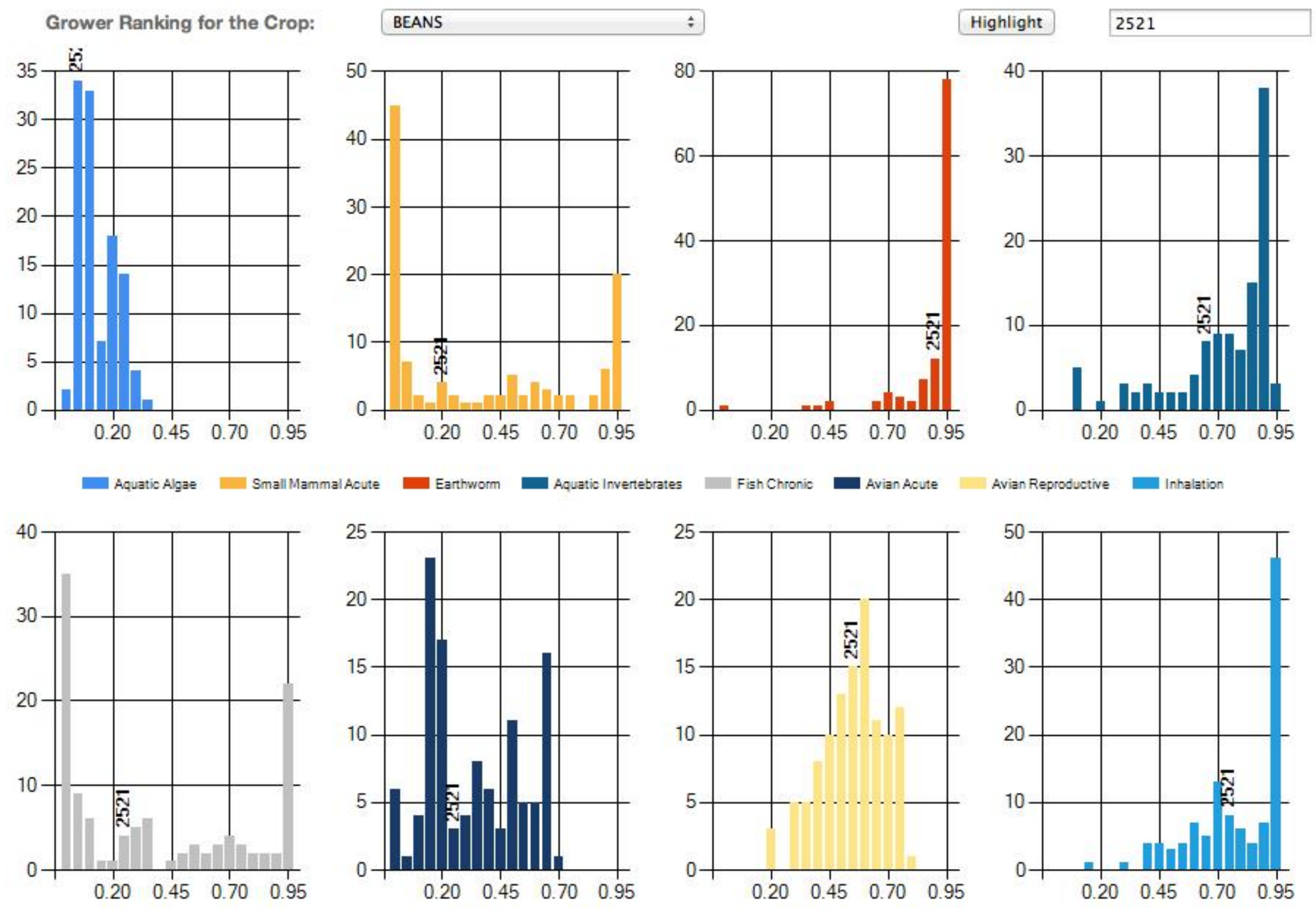
Possible to rank commodities, pesticides, farmers associated with higher risks

Distribution of risks by farm



Processor, certifier, farmer can identify priorities for management responses

Programs are highly variable, farm to farm (example for a very uniform green bean production system in the Willamette Valley, OR



Pesticide risk reduction in West Africa

Jepson, P. C.[1], Guzy, M.[1], Blaustein, K.[1], Sow, M.[2], Sarr, M.[3]

[1]Integrated Plant Protection Center, Oregon State University; [2]ENDA, Dakar, Senegal; [3]UN Food and Agriculture Organization, Senegal; [4]Department of Environmental and Molecular Toxicology, Oregon State University

OSU

FAO GEF/PRM program in W. Africa

Sustain production, reduce pesticide risks, enable adaptive management and appropriate technology use

All sites were discrete production systems with local farm families that supplied all the labor for production

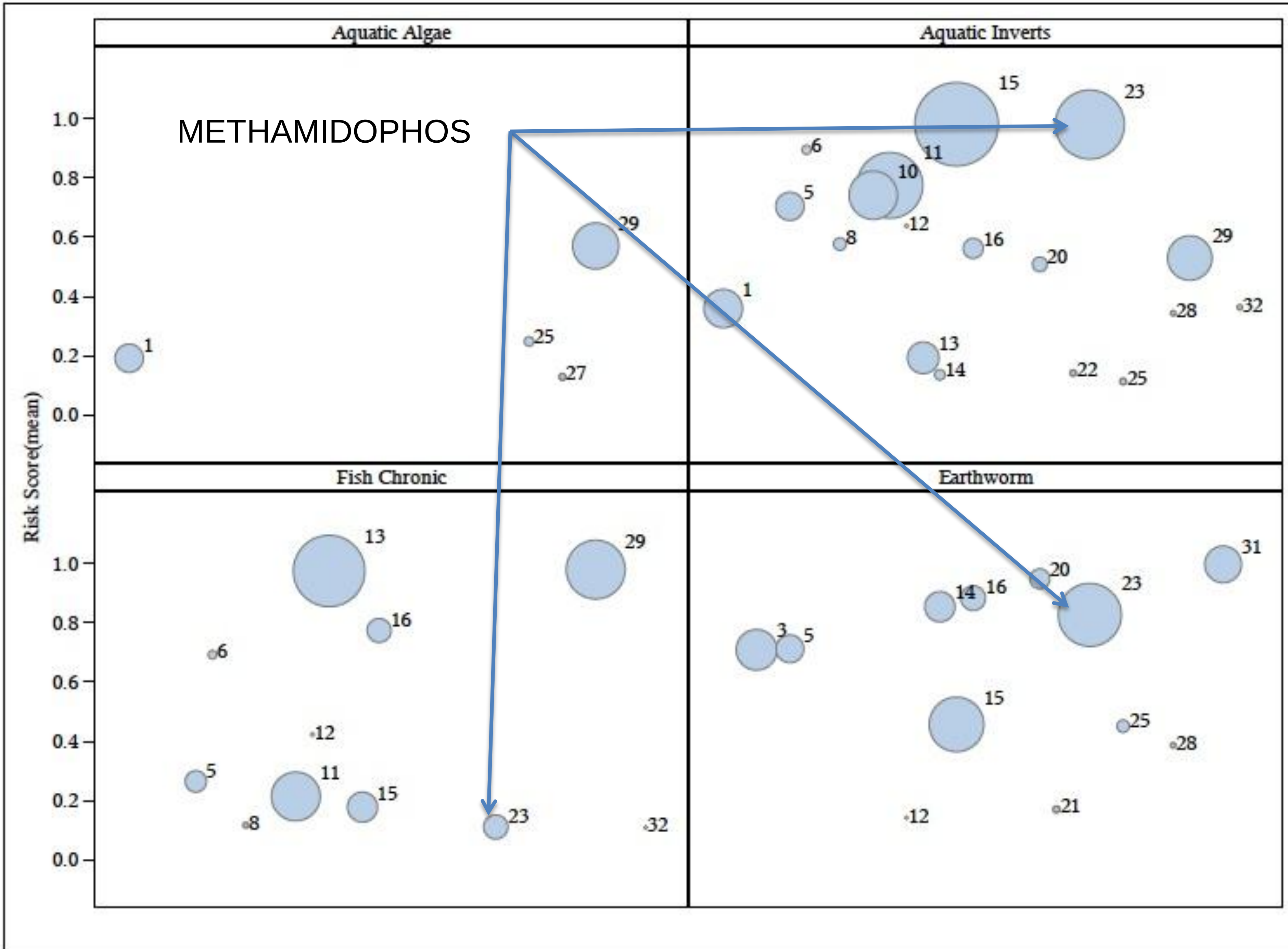
Regional risk over all sites in West Africa and all crops

Area of impact = risk score * area over which product applied

(After "Bird Kill Hectares" of Mineau & Whiteside, *Environmental Toxicology and Chemistry* **25**, 1214-1222)

Example: of 1591 ha surveyed, methamidophos impact areas for each PRiME index from Jepson et al, 2014: Phil. Trans Royal Soc, in press

Risk index	Impact area (ha)
Aquatic algae	**0**
Aquatic invertebrates	**517**
Fish chronic	**63**
Earthworm	**431**
Small Mammal	**466**
Avian acute	**265**
Avian reproductive	**160**
Bystander inhalation	**99**



Aquatic Algae
Aquatic Inverts
Fish Chronic
Earthworm
METHAMIDOPHOS
Risk Score(mean)
1.0
0.8
0.6
0.4
0.2
0.0
1
25
27
29
15
23
6
11
10
5
12
8
16
20
29
1
28
32
13
14
22
25
13
29
16
6
12
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8
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16
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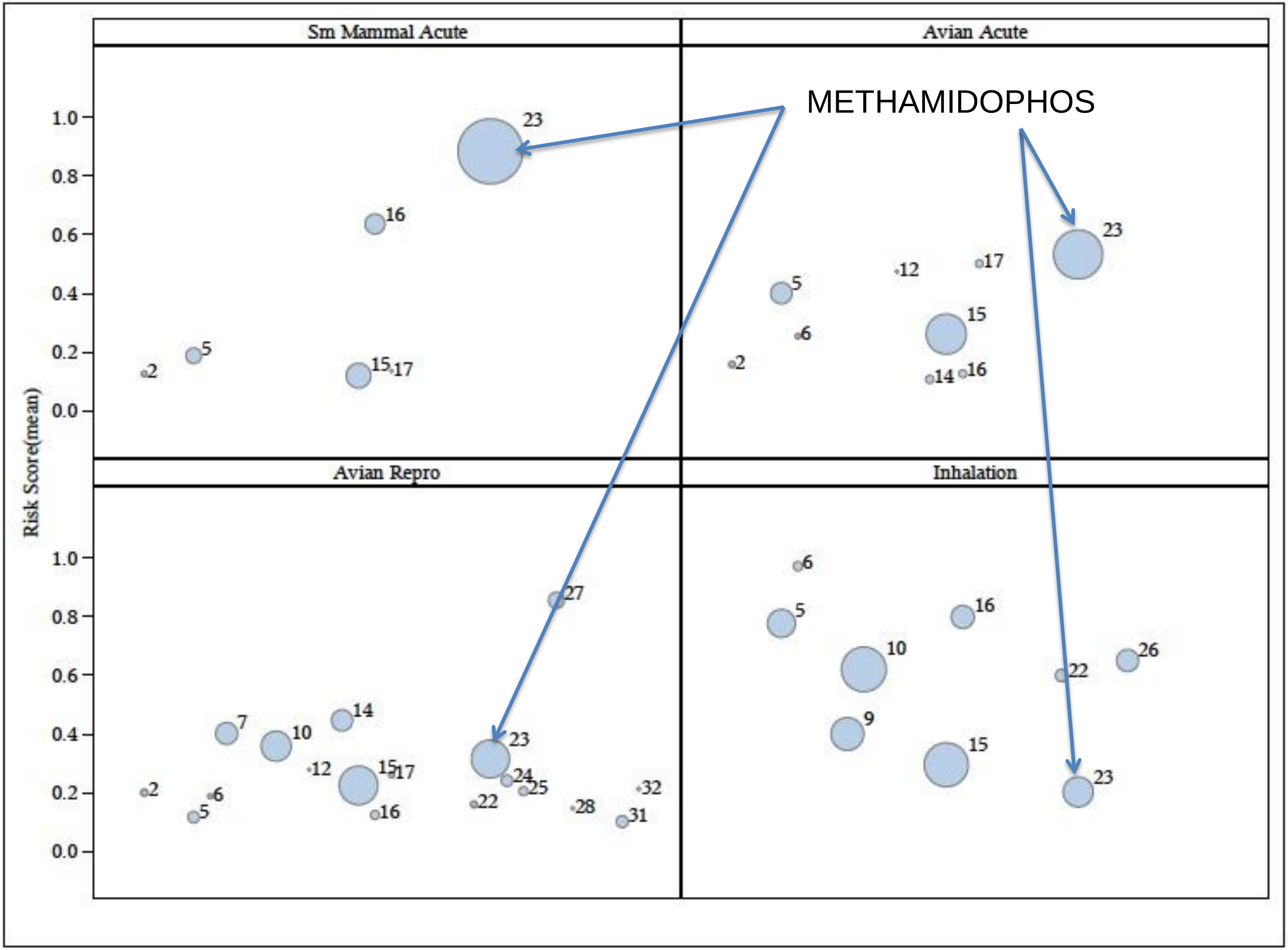
5
15
25
28
21
12



Sm Mammal Acute
Avian Acute
Avian Repro
Inhalation
Risk Score(mean)
METHAMIDOPHOS
1.0
0.8
0.6
0.4
0.2
0.0
23
16
5
2
15
17
12
6
14
22
24
25
27
28
31
32
7
10
9
26

Conclusions

In order to implement a recovery component to risk assessment:

1. **Quantifiable goals are required, that can be tracked in the real world – how else will you know if the approach is effective?**
2. **Monitoring results can be fed back to farmers, regulators and other stakeholders**
3. **The limitations of any approach that is not based on the attributes of a specific system must be understood before it is implemented in regulatory decision making**
4. **The uncertainties associated with agricultural landscapes will remain high**
5. **The ERT approach for estimating recovery time employs currently available data, and addresses biodiversity**
6. **Research models can explore ranges in actual recovery time, but are limited at present**
7. **Analysis must consider real pesticide programs, climatic variation, and patterns of use to isolate high risk cases**