Vulnerability to Transboundary Pests and Diseases under Climate Change

Bob Sutherst
School of Integrative Biology, University of Queensland, Australia
Vulnerability = Impacts x Adaptability

Impacts = Exposure x Sensitivity

Adaptability = Robustness and Sustainability of Response Options

SCALE: Regional
       Industry/Ecosystem
- Customise definition of *Vulnerability* for biosecurity purposes
- Develop a global change *context* for climate change analyses
- IPCC 2007 climate change *scenarios* and examine their role
- Methods & Data
- Modelling Results & Conclusions
- Questions
- List some candidate target species
**Vulnerability - Biosecurity under Climate Change**

Vulnerability Fn (Impact of incursions x Cost Border Security)

Border Security Fn (Source reduction + Pathway hygiene + Barriers to entry)

**Impacts =** Exposure (Sector/Region) x Sensitivity @ Sources & Destinations

$\Delta$ Impacts CC = Current Impacts +/- Incremental Change

**Sensitivity Fn (Location x Species x CC Scenario)**

Vulnerability = Social, Economic & Environmental outcomes
Climate Change

Risks from Pests (Pests & Diseases)

- Land use, water storage and irrigation
- Atmospheric composition, CO₂...
- Climate Change
- Climate Variability
- Human Health & Labour
- Species interactions with hosts, predators, competitors etc
- Trade & Human movements
- Industrial & Agricultural Chemical Pollution
IPCC 2007

Top Boreal Winter

Bottom Boreal Summer
Temperatures vary geographically, seasonally & daily

b) Soil moisture

[Map showing soil moisture distribution with color scale from -25 to 25%]
Realities of Global Change R&D

- Multiple, interactive drivers of global change
- Spatially heterogeneous climatic signals
- Multiple species of pests & diseases
- Multi-trophic impacts
- Global experimentation impossible
- Reliance on models to explore impacts
- Outputs relate to policy
  - Regional, national or global
  - Industry
  - Linked trading regions
  - Economic, social and environmental

**CONCLUDE:** Parsimonious approaches needed
Global Change R&D Needs

- Hierarchical and Generic approaches & tools
- Models that work everywhere
- Spatial scale for regional or industry assessments
- Integrated risk assessments linking (coupled) crop and pest models
- Socio-economic models for policy

Global community needs:
* common tools and languages
* synergy from collaboration & networking
Global change - User Questions

**Policy**
What **Industries** are vulnerable?
What **Regions** are vulnerable?
What will be the cost of **Adaptation**?

**Individuals**
What is global change going to cost me?
Do I need to adapt and if so when?

Spatial analyses

Plot-based temporal analyses
DYMEX Modular Modelling Toolkit for Biologists

- Re-useable & exchangeable modules
- Global change drivers and their interactions
- Biological processes and attributes to associate with lifecycle stages
- 'Inherit' / enhance properties
- Library of functions
- Spatial modelling platform
A Risk Assessment Toolkit

Model species responses to climate

Modular population modelling

Designed by Biologists for Biologists
Observed responses to climate change - ticks
Myzus persicae at Rothamsted 1965 - 2003

$r^2 = 0.600$

$P < 0.001$

Jan - Feb mean screen temperature °C

Total to 1st July (n+1)

(Mean 1965-03)

(2050)
STEP 1: Know your environmental gradients

Temperature

Moisture

Hydro-Thermal
Chryomya bezziana – Old World screw-worm fly
Asia – China has sensitivity

Current

+2°C

+2°C +20% Rn
Potential responses to climate change

Chryomya bezziana - Old World screw-worm fly

Southern Africa – Source & Destination?
Sensitivity to Ceratitis capitata – Medfly +2°C

Current Climate
Invasive Species
Quagga and Zebra Mussels

In just a few years, quagga mussels have gone from a relatively rare find to the dominant invasive mussel in Lake Michigan. Biologists worry quaggas could prove much more disruptive than their closely related cousin, the zebra mussel, because they are more effective filter feeders, and they can live and breed in colder, deeper waters.

Quagga Mussel
*Dreissena bugensis*

Zebra Mussel
*Dreissena polymorpha*

<table>
<thead>
<tr>
<th>Feature</th>
<th>Quagga Mussel</th>
<th>Zebra Mussel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell</td>
<td>Rounder sides, convex underside. No ridge. When placed on its underside, the quagga mussel will topple.</td>
<td>Triangular shape, underside flat. Obvious ridge between side and bottom. When placed on its ventral side, it will remain upright.</td>
</tr>
<tr>
<td>Color</td>
<td>Pale near hinge, dark concentric rings on the shell.</td>
<td>Variable colors and patterns, usually dark.</td>
</tr>
<tr>
<td>Underside</td>
<td>Small ventral groove near the hinge.</td>
<td>Large groove in middle of flat side; allows tight hold on rocks.</td>
</tr>
<tr>
<td>Depth in Lake</td>
<td>3 to 541 feet; expected to go deeper over time.</td>
<td>3 to 98 feet; rarely found below 50 feet.</td>
</tr>
<tr>
<td>Temperature Tolerance</td>
<td>39 to 68 degrees</td>
<td>54 to 68 degrees</td>
</tr>
<tr>
<td>Spawning Temperature</td>
<td>Minimum 50 degrees; a female quagga mussel with mature reproductive organs was found in Lake Erie at a temperature of 42 degrees.</td>
<td>Minimum 56 degrees; can survive in stagnant water with uniform temperature but cannot reproduce there.</td>
</tr>
</tbody>
</table>

Source: USGS; Sea Grant Pennsylvania
Zebra Mussel – An Opaque Risk Assessment
Seasonal Migration

M. vetustissima Australian Bushfly

[Map showing the migration pattern of M. vetustissima across different months, with color-coded regions indicating source and sink areas.]
Marine homo-climates
Vulnerability of Australian Horticulture to Pests under Climate Change

Total Cost = $28.5m p.a.
Current

Queensland Fruit Fly

Total Cost = $21m
Current

Light Brown Apple Moth

Regional Vulnerability

EI Value

<table>
<thead>
<tr>
<th>El Value</th>
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<tbody>
<tr>
<td>0 to 1</td>
</tr>
<tr>
<td>1 to 5</td>
</tr>
<tr>
<td>5 to 10</td>
</tr>
<tr>
<td>10 to 20</td>
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<td>20 to 40</td>
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<tr>
<td>&gt;20</td>
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<td>10 to 20</td>
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<td>5 to 10</td>
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<td>1 to 5</td>
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<td>-1 to 1</td>
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<tr>
<td>-10 to -5</td>
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<tr>
<td>-20 to -10</td>
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<td>&lt; -20</td>
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+1.0°C

+2.0°C
## Industry Vulnerability

### Changes in Pest Damage
(from CLIMEX Ecoclimatic Index) (A$millions)

<table>
<thead>
<tr>
<th></th>
<th>Queensland Fruit Fly</th>
<th>Light Brown Apple Moth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industry</strong></td>
<td><strong>+ 1°C</strong></td>
<td><strong>+ 1°C</strong></td>
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<tr>
<td>Oranges</td>
<td>+ 1.8</td>
<td>- 1.3</td>
</tr>
<tr>
<td>Apples</td>
<td>+ 2.1</td>
<td>+ 0.5</td>
</tr>
<tr>
<td>Pears</td>
<td>+ 0.9</td>
<td>+ 0.2</td>
</tr>
<tr>
<td></td>
<td><strong>+ 2°C</strong></td>
<td><strong>+ 2°C</strong></td>
</tr>
<tr>
<td>Oranges</td>
<td>+ 3.5</td>
<td>- 4.7</td>
</tr>
<tr>
<td>Apples</td>
<td>+ 5.6</td>
<td>+ 0.7</td>
</tr>
<tr>
<td>Pears</td>
<td>+ 2.8</td>
<td>+ 0.2</td>
</tr>
<tr>
<td>Grapes</td>
<td></td>
<td>- 1.9</td>
</tr>
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Mechanistic prediction

*Phytophthora cinnamomi*

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Fig. 5. Mapping of $F_{0.05}$ and $F_{0.5}$ in *Quercus rubra* frequencies of years with *Phytophthora cinnamomi* annual survival rate below the 0.05 and 0.5 thresholds for periods 1968-1998 and 2070-2099.
1. Establish **Benchmarks** of Current Biosecurity status
   1. Incursions
   2. Establishments
   3. Impacts: Costs of Biosecurity

2. Monitor **Indicators** of Change in Biosecurity
   1. Rates of Invasions by Foreign Species
   2. Rates of crop, livestock, forest and fish losses
   3. Costs of Biosecurity

3. **Accelerate Adoption** of New Technology
   1. Work-shopping Tools
DYMEX modular modelling of biological organisms.

Are you Managing Pest, Weed and Pathogen Problems?

Workshops
- Group’s Expectations
- Model Specifications
- Data Collation
- Model Formulation & Testing
- Analysis of System
- Design of Management Strategies
- Future Plans

Enhanced Risk Assessment, Management and Communication

Collaborative Networks sharing Data & Results

Model with Group’s Ownership

Identify Research Priorities

Group Training by Involvement

Enhanced Pest, Weed and Pathogen Management and Communication Problems?
THE END