"Where the bee sucks, there suck I" An integrating decision support system for pollinator abundance

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The importance of pollinators

Pollinators

- Bees and other pollinators play a crucial role in food production
- Improve crop quality and quantity to contribute the equivalent of more than £500 million (AUD 900 million) a year to UK agriculture and food production
- Vital to our wider, natural ecosystems, wider biodiversity and ensuring healthy and productive ecosystems

.

Pollinator-dependent food products are important contributors to healthy human diets and nutrition and it is estimated that over 70% of important food crops worldwide are dependent upon pollinators

Key question

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How can we network together inputs from disparate expert domains in a coherent way, taking account of inherent uncertainties, so that different policy options can be compared in order to support decision-making?

We have contributed a methodology for doing this in a general system of this type and identified some frameworks which can be used to build such an integrating decision support system. We are now working to put theory into practice, starting to design an IDSS to evaluate policies designed to support household food security, pollinator abundance, digital preservation, policing & other security applications.

Generalisation: Integrating Decision Support systems

A formal & defensible statistical methodology to draw together inferences when:

- Users are decision *Centres*
- Centres motivated to act as a single coherent unit for a common goal
- Consensus about utility structure to scrutinise efficacy of candidate policies
- Consensus about an overarching description of dynamics driving the process.
- Consensus about who is expert about what, to identify appropriate expert panels
- Expert judgements from disparate panels of experts
- Each component panel informed by complex models & huge data sets

Generalisation: Integrating Decision Support systems

A single, comprehensive probabilistic model is inappropriate

- infeasibly large
- no shared structural assumptions so no centre can 'own' the full joint distribution
- dynamic revisions lead to fast obsolescence

Full technical details in

Coherent Frameworks for Statistical Inference serving Integrating Decision Support Systems *Jim Q. Smith, Martine J. Barons & Manuele Leonelli*, submitted & on arXiv: 1507.07394

Common Knowledge assumptions

- **Utility consensus:** *All agree on the class* $\mathbb{U}$ *of utility functions supported by the* **IDSS***.*
- **Policy consensus:** *All agree the class of decision rules* $d \in \mathbb{D}$ *that might be examined by the* **IDSS***.*
- **Structural consensus:** *All agree* **structural consensus set** $\mathbb{S}$ *of the variables* $\boldsymbol{Y}$ *defining the process of the developing crisis, together with a set of qualitative statements about the dependence between various functions of* $\boldsymbol{Y}$ *and* $\boldsymbol{\theta}$*.*

Definition: CK class

Call the set of common knowledge assumptions shared by all panels and which contains the union of the utility, policy and structural consensus $(\mathbb{U}, \mathbb{D}, \mathbb{S})$ the *CK class*.

Technical structure

- Panels G_i, $i = 1, 2, \ldots, m$, deliver belief summaries $\Pi_i^y \triangleq \{\Pi_i^y(d) : d \in \mathbb{D}, \}$ to IDSS, typically, various moments of certain functions of $\boldsymbol{Y}_i$ (expectation, variance, etc.)
- All panellists make their inferences in a parametric or semi-parametric setting $\boldsymbol{Y}$ is parametrised by $\boldsymbol{\theta} = (\boldsymbol{\theta}_1, \boldsymbol{\theta}_2, \ldots, \boldsymbol{\theta}_m) \in \Theta(d) : d \in \mathbb{D}$ and the parameter vector $\boldsymbol{\theta}_i$ parametrises the G_i's relevant sample distributions.
- Panels are *variationally independent* i.e. the parameter space can be written as the product space $\Theta(d) = \Theta_1(d) \times \Theta_2(d) \times \ldots \times \Theta_m(d),\ d \in \mathbb{D}$.

Examples of sound and distributive frameworks

- Staged trees
- Bayesian Networks
- Chain event graphs
- Decomposable graphs
- Multiregression dynamic models

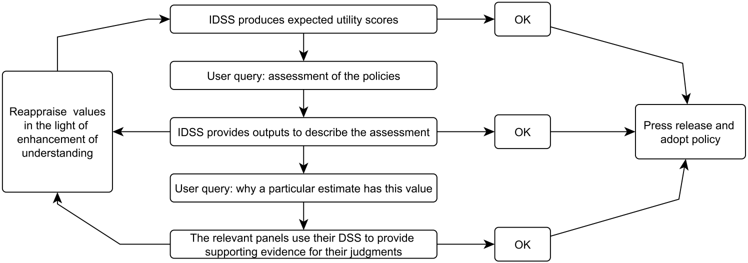


Figure: Manuele Leonelli & James Q. Smith(2015) Bayesian Decision Support for complex systems with many distributed experts Ann Op Res

Pollinator DBN for the UK system

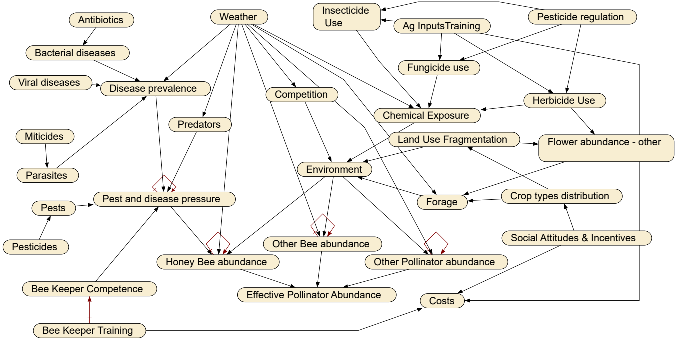
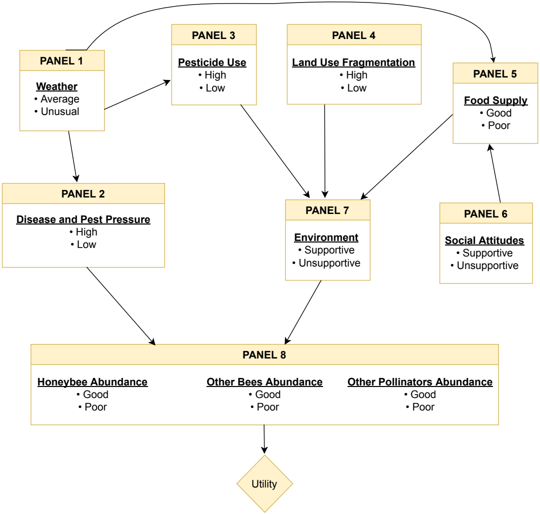


Figure: DBN including all factors affecting pollinator populations based on domain literature and expert opinion.

IDSS showing expert panels for the UK system



Utility

Utility

Utility $= \frac{1}{3} \times p(\text{Honeybees abundance} = \text{Good}) + \frac{1}{3} \times p(\text{Other bees abundance} = \text{Good}) + \frac{1}{3} \times p(\text{Other pollinators abundance} = \text{Good})$.

Policymakers can vary the weighting by region, crop, etc.,
Evaluate different policy strategies, Cost benefit analyses
Mutual information ($I(X;Y)$) between nodes X and Y is

$$I(X;Y) = H(X) - H(X|Y) = \sum_x \sum_y \log_2 \frac{p(x,y)}{p(x).p(y)}, \quad (1)$$

where $H(X)$ is the marginal entropy of X, $H(X|Y)$ is the conditional entropy of X given Y and $I(X;Y)$ in bits.

Scenarios

Analyse the short and medium term effects of various candidate policies and events

Scenarios

- Scenario 1: Decreasing Pesticide Use
  - 1a) pesticide use is set to "Low" for only one year,
  - 1b) pesticide use is set to "Low" for five years
  - 1c) pesticide use is set to "Low" for ten years.
- Scenario 2: Improving Social Attitudes and Reducing Land Use Fragmentation
- Scenario 3: Reducing Disease and Pest Pressure
- Scenario 4: Decreasing Pesticide Use, and Reducing Disease and Pest Pressure
- Scenario 5: Worsening Weather Conditions

Results

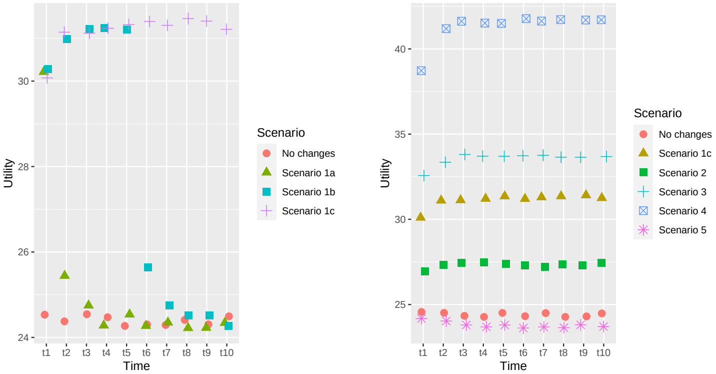


Figure: Plots showing the utility scores for each of the ten years under (a) the three cases of Scenario 1 and (b) under Scenario 1c and Scenarios 2, 3, 4 and 5 when compared to having no changes in the IDSS.

Decision support for Australia

Background

- Varroa-free status
- June 2022 discovery NSW Newcastle
- Higher burdens inland suggest much earlier illegal import
- Surveillance:
  - Miticide + sticky board
  - sugar shake
  - alcohol wash
  - soapy water

Similar scenario in New Zealand in 2000, 2006

Main differences

Australia / UK differences

- Endemic *Varroa Destructor* mite
- Feral colonies
- Agriculture therefore pesticide exposure
- Peripatetic beekeeping
- Beekeeper training culture in UK, BBKA
- Registration with UK BeeBase (Animal and Plant Health Agency); receive BeeBase alerts
- Honey per hive 100kg peripatetic, 20kg static
- Distances, mixing
- National Pollinator Strategy
- State government

Conclusion

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- IDSS is effective for pollinator abundance
- UK-based IDSS needs adaptations
- Data are always a problem for insects
- Structured expert judgement for data gaps

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