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# From Assessments to Decisions: How to Leverage Bayesian Networks

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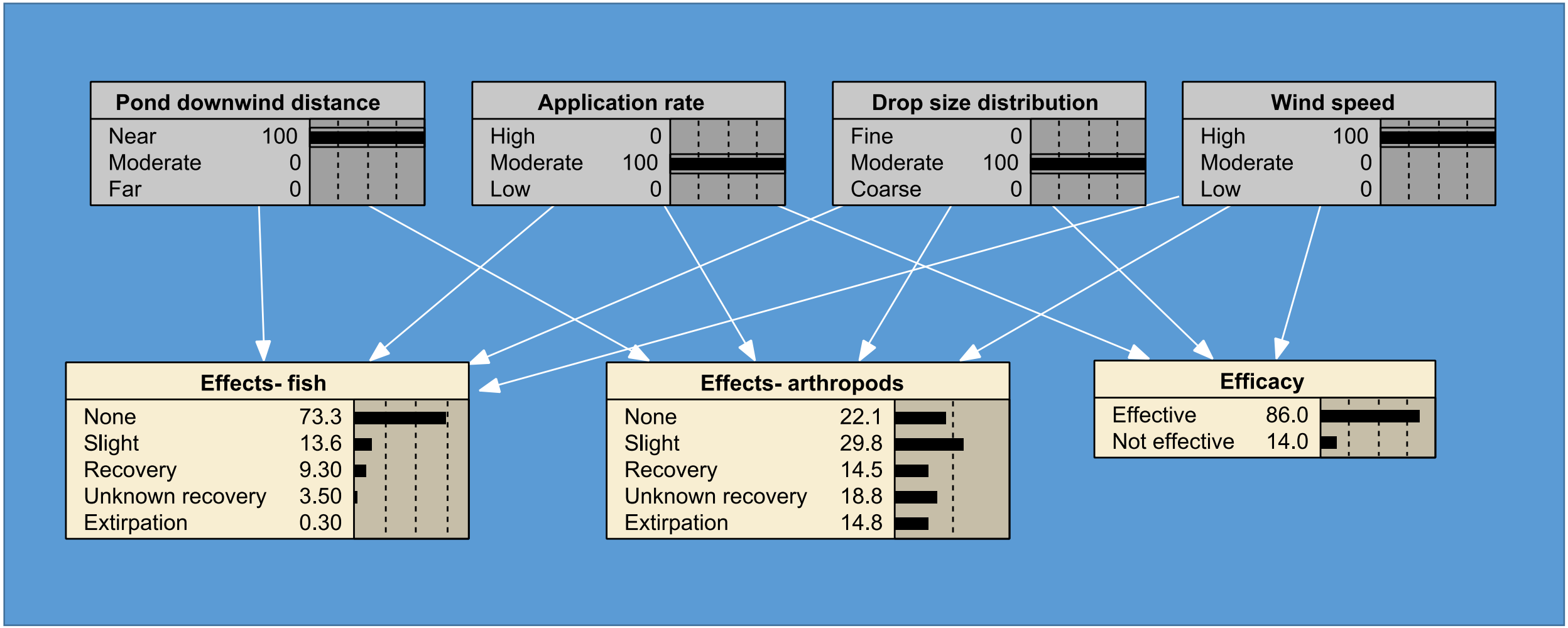
# Disclaimer

*The views expressed in this presentation are those of the author and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency*

# Example Pesticide BN for Risk Assessment




Carriger, J.F. and Newman, M.C., 2012. Influence diagrams as decision-making tools for pesticide risk management. *Integrated environmental assessment and management*, *8*(2), pp.339-350.

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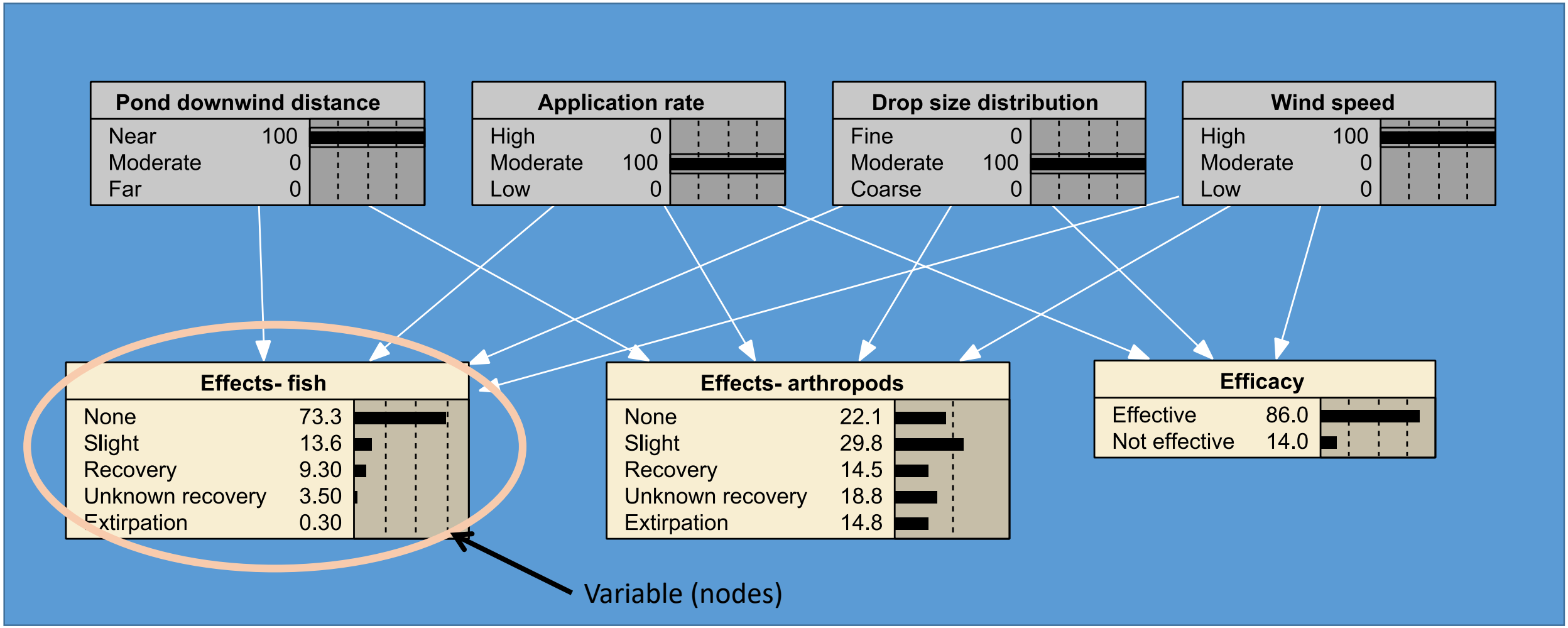


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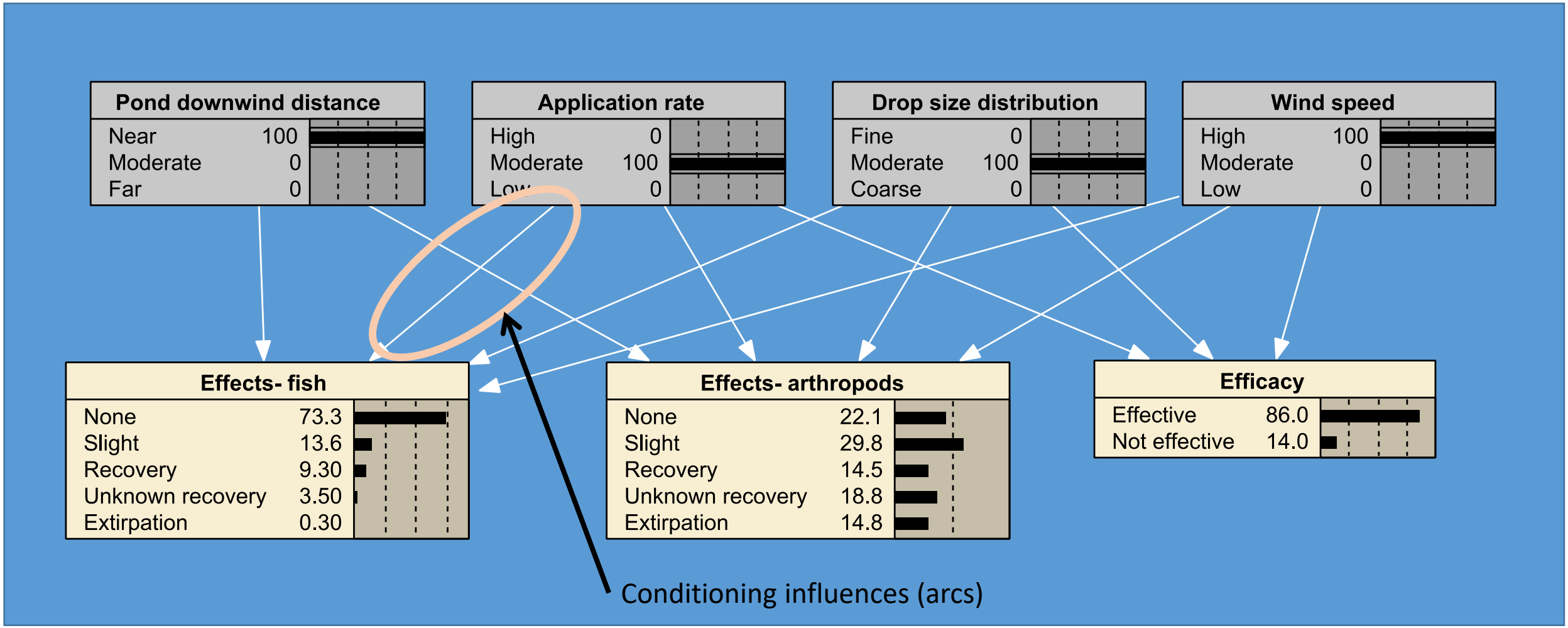


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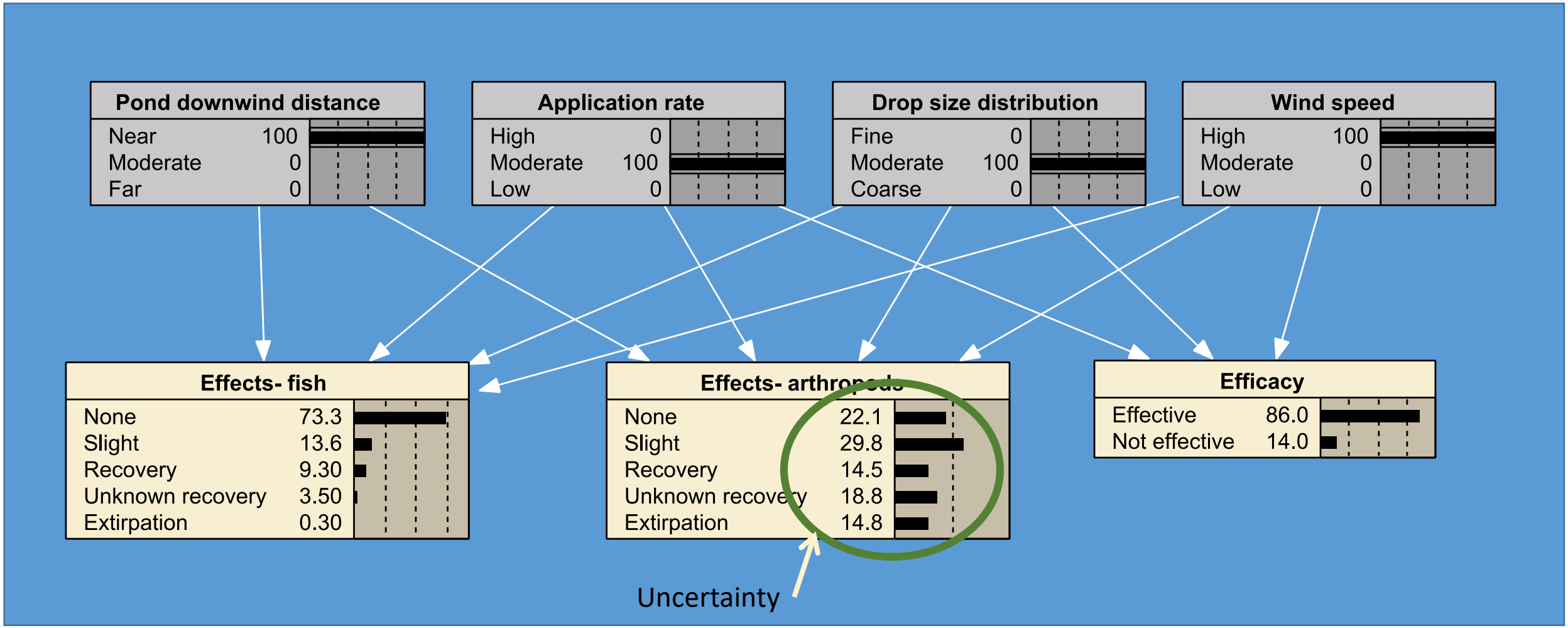


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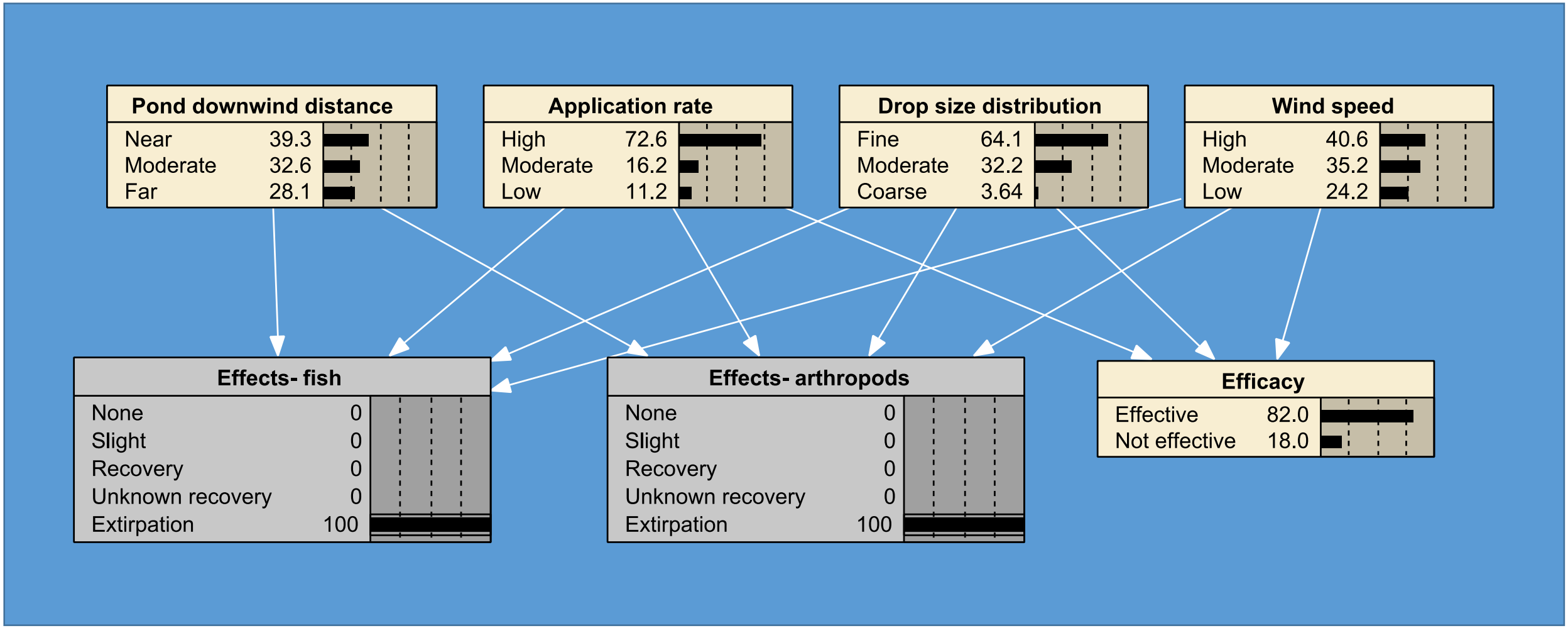
# Diagnostic inference (effects to causes)

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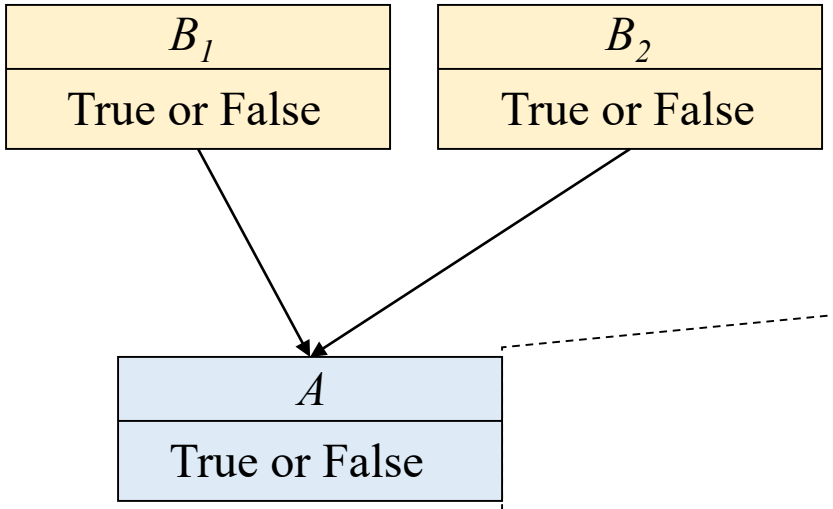
# Quantification- the CPT engine




| | | $A$ T | $A$ F |
|---|---|---|---|
| $B_1$ T | $B_2$ T | **74** | **26** |
| $B_1$ T | $B_2$ F | **48** | **52** |
| $B_1$ F | $B_2$ T | **83** | **17** |
| $B_1$ F | $B_2$ F | **57** | **43** |

Carriger, J.F. and Newman, M.C., 2012. Influence diagrams as decision-making tools for pesticide risk management. *Integrated environmental assessment and management*, *8*(2), pp.339-350.

# How can causal BNs support RA/DA?

- Knowledge representation
  - Multi-disciplinary expert-developed causal models
  - Rapid “on the fly” development to capture workshop conversations
- Identify and evaluate components
  - Objectives
  - Performance measures
  - Actions/alternatives
- Informative for understanding the causal interactions influencing decision making (Carriger et al. 2018)
- “We think about the world like this” (Pearl & Mackenzie 2018)

Pearl, J. and Mackenzie, D., 2018. *The Book of Why: The New Science of Cause and Effect*. Basic Books.

Carriger, J.F., Dyson, B.E. and Benson, W.H., 2018. Representing causal knowledge in environmental policy interventions: Advantages and opportunities for qualitative influence diagram applications. *Integrated environmental assessment and management*, *14*(3), pp.381-394.

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# For adaptive management (Nyberg et al. 2006)

- Develop Bayesian networks as “testable impact hypotheses”
- Refine hypotheses with new experimental work
- Refinement includes
  - Structure
    - Remove/add nodes
    - Change relationships
  - Probabilities
  - Node definition
- Use the Bayesian network(s) at each step along the way to communicate the knowledge base and uncertainties

Nyberg, J.B., Marcot, B.G. and Sulyma, R., 2006. Using Bayesian belief networks in adaptive management. *Canadian Journal of Forest Research*, *36*(12), pp.3104-3116.

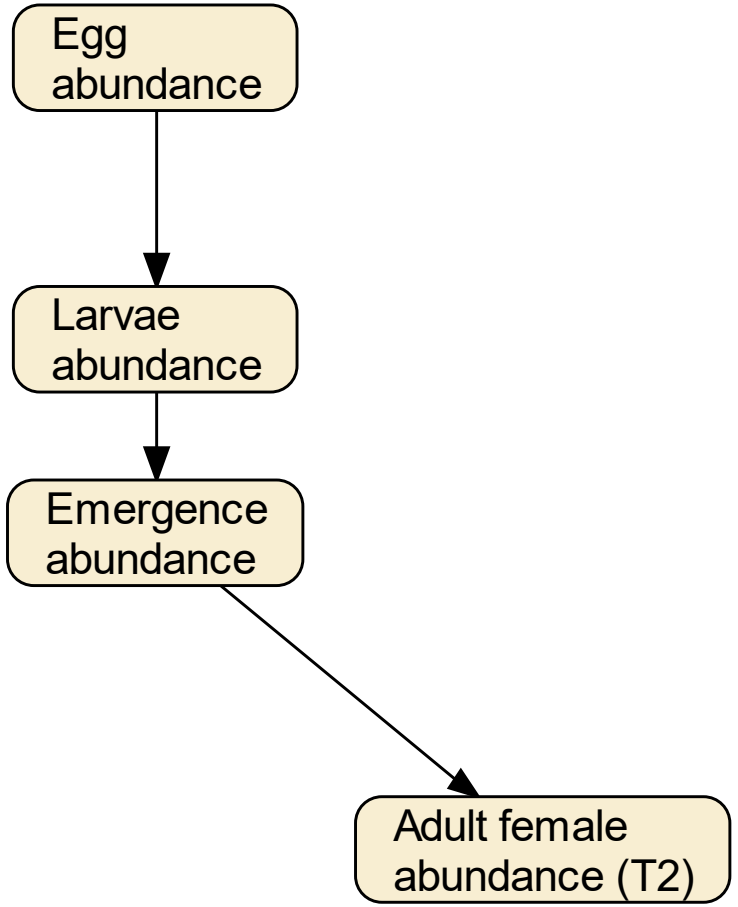
# Adaptive management (Nyberg et al. 2006)

| | |
|---|---|
| 1 Assess the problem or opportunity | **Develop causal structure, probabilities, sensitivity analysis** |
| 2 Design a management experiment | **Design and select management experiments to be tested with BN** |
| 3 Implement the experiment | **Focus implementation based on BN** |
| 4 Monitor system responses | **Compare with BN predictions, ensure detectability of BN events** |
| 5 Evaluate outcomes and learn | **Update BN with new understanding** |
| 6 Adapt future decisions | **Use BN for future decisions and experiments** |

Nyberg, J.B., Marcot, B.G. and Sulyma, R., 2006. Using Bayesian belief networks in adaptive management. *Canadian Journal of Forest Research*, *36*(12), pp.3104-3116.

# Assessment network (hypothetical)

Tan nodes- chance nodes, random variables



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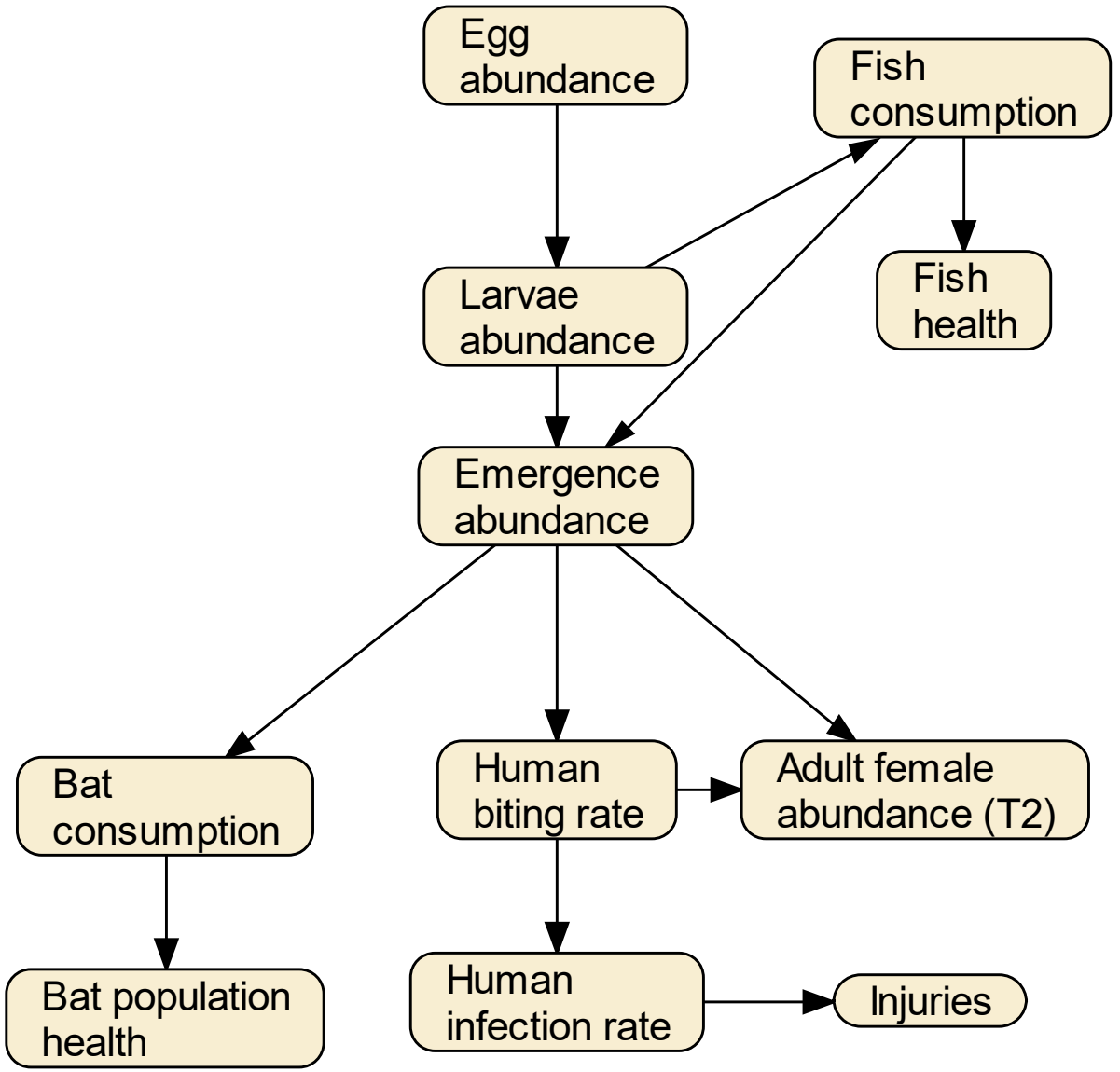

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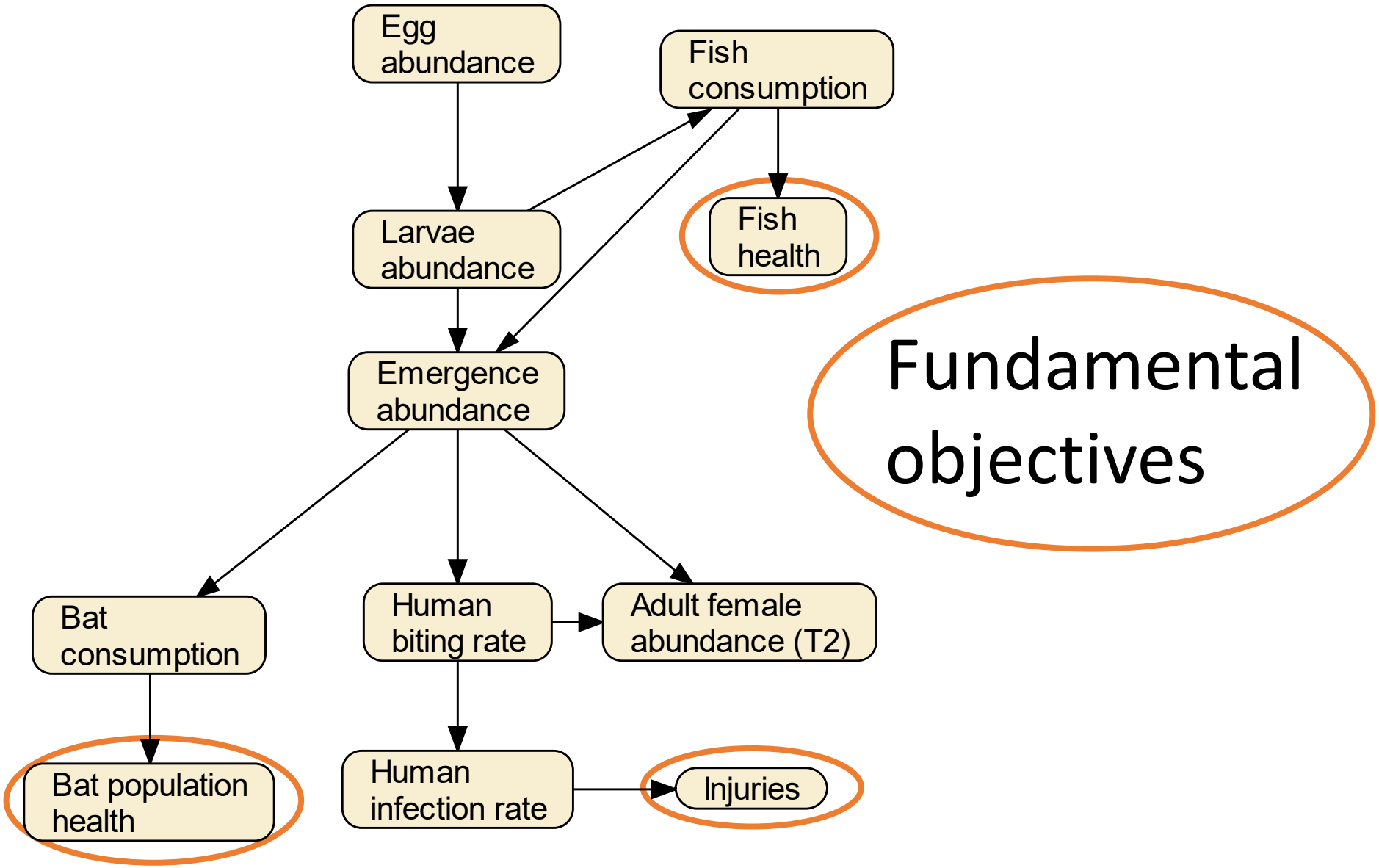
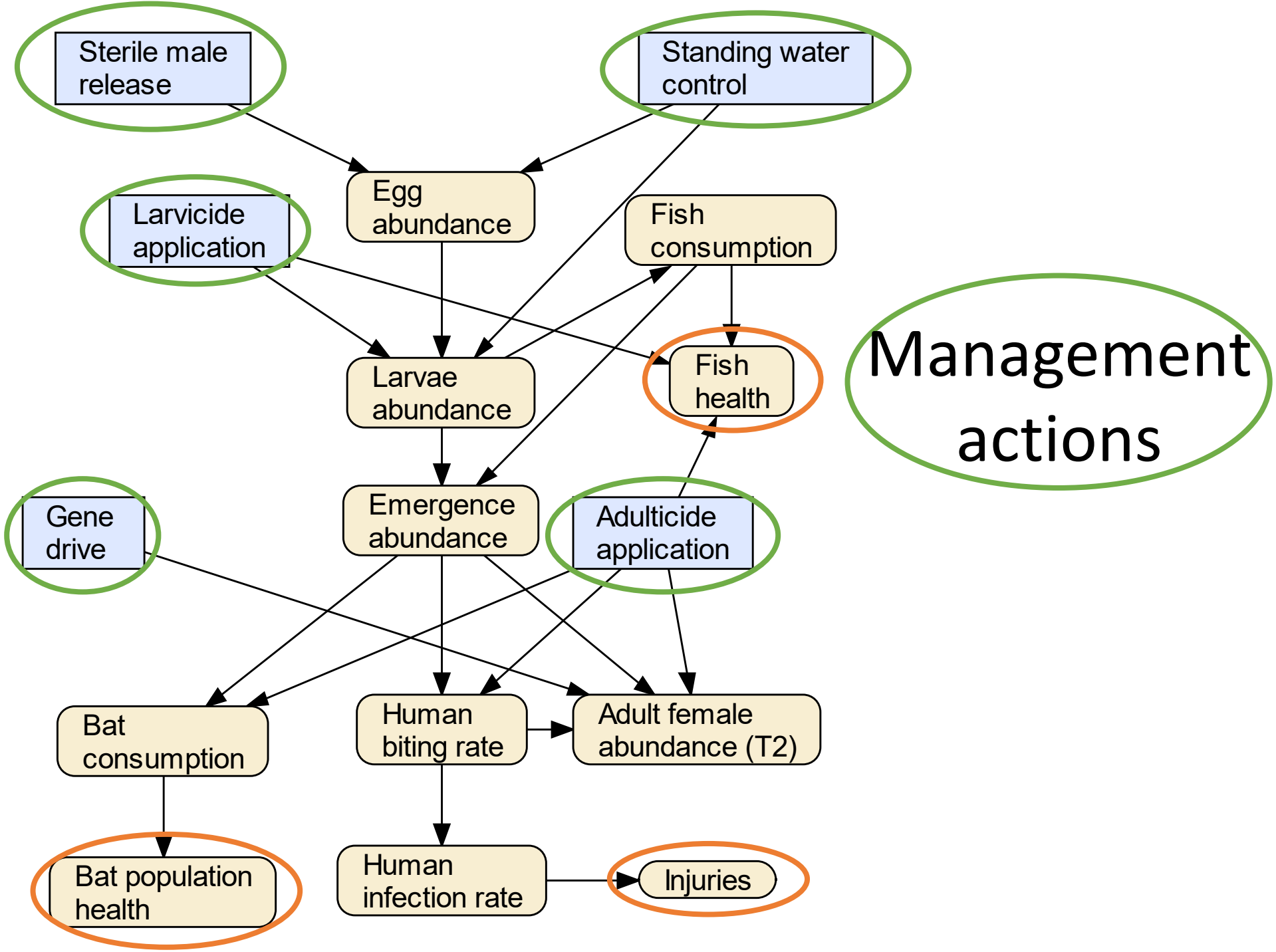


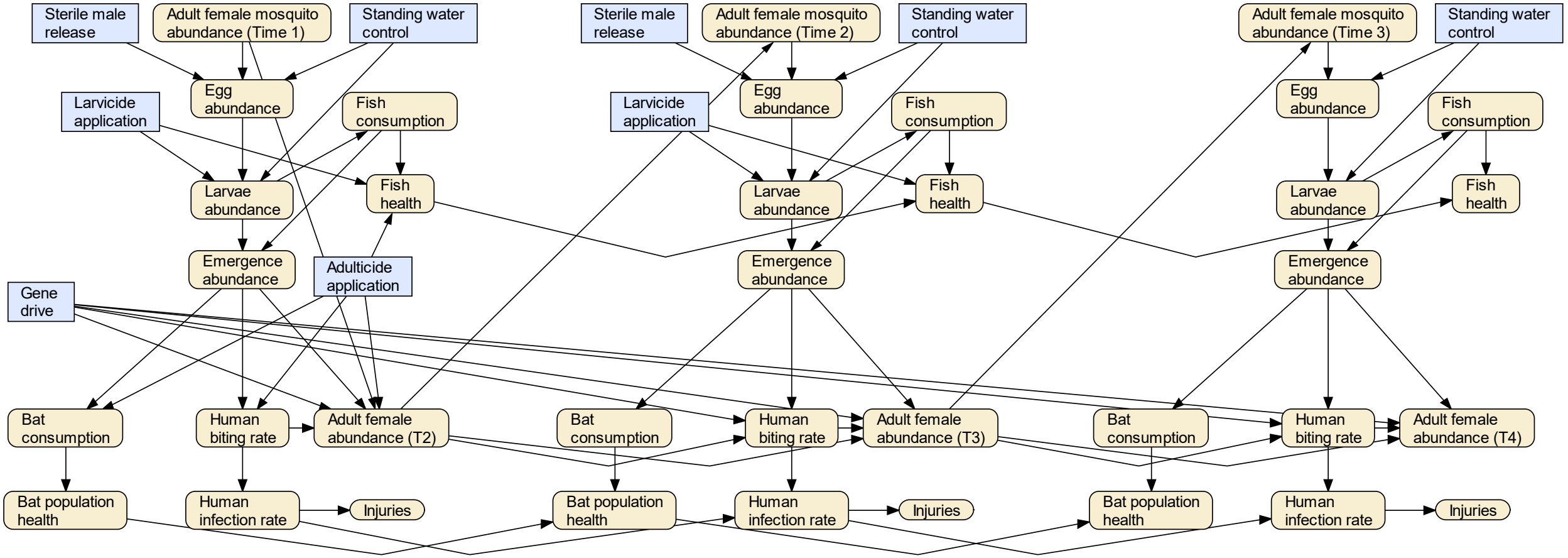
# Management network (hypothetical)

Tan nodes- chance nodes, random variables

Blue nodes- management actions



# Temporal application



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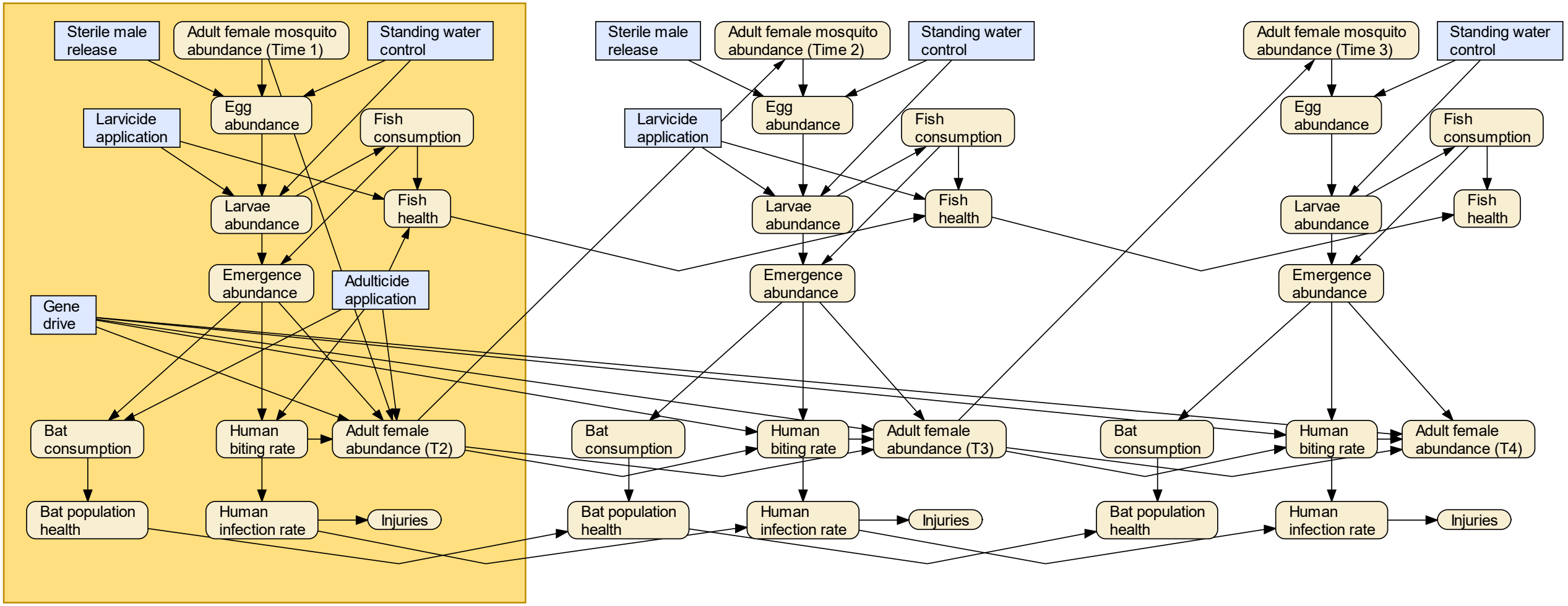
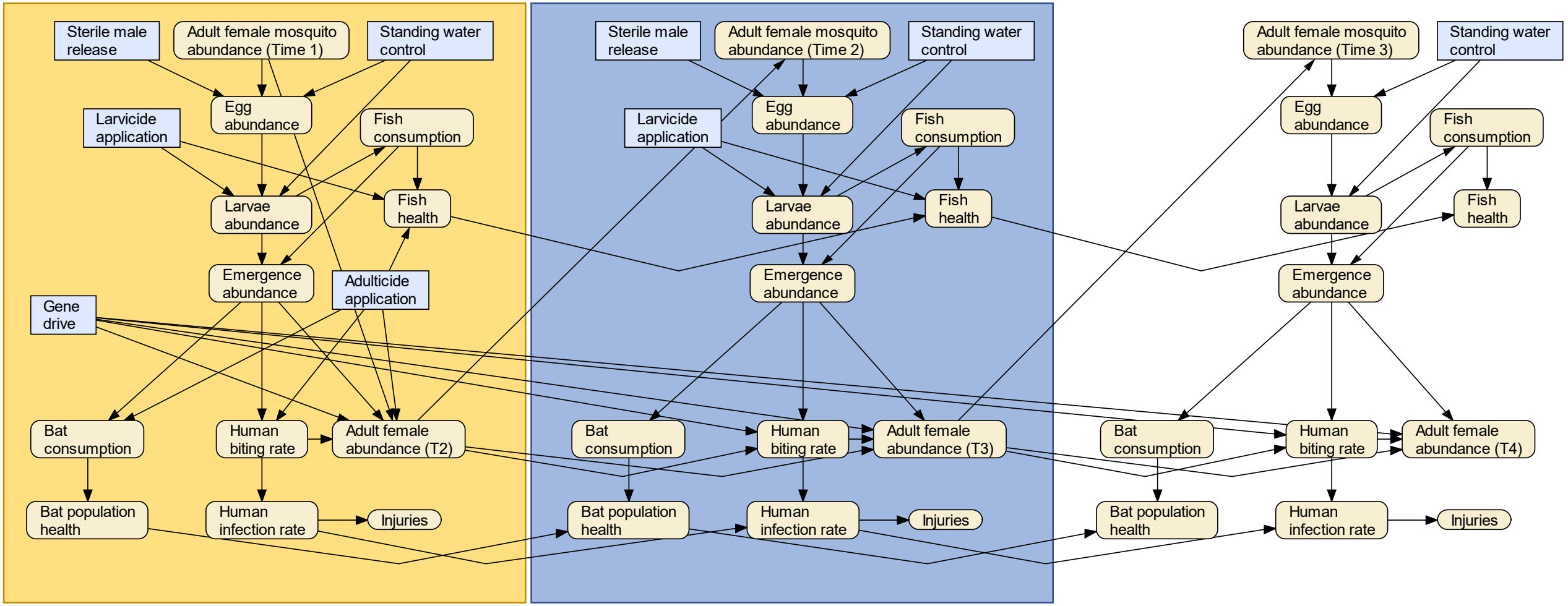



Time 1

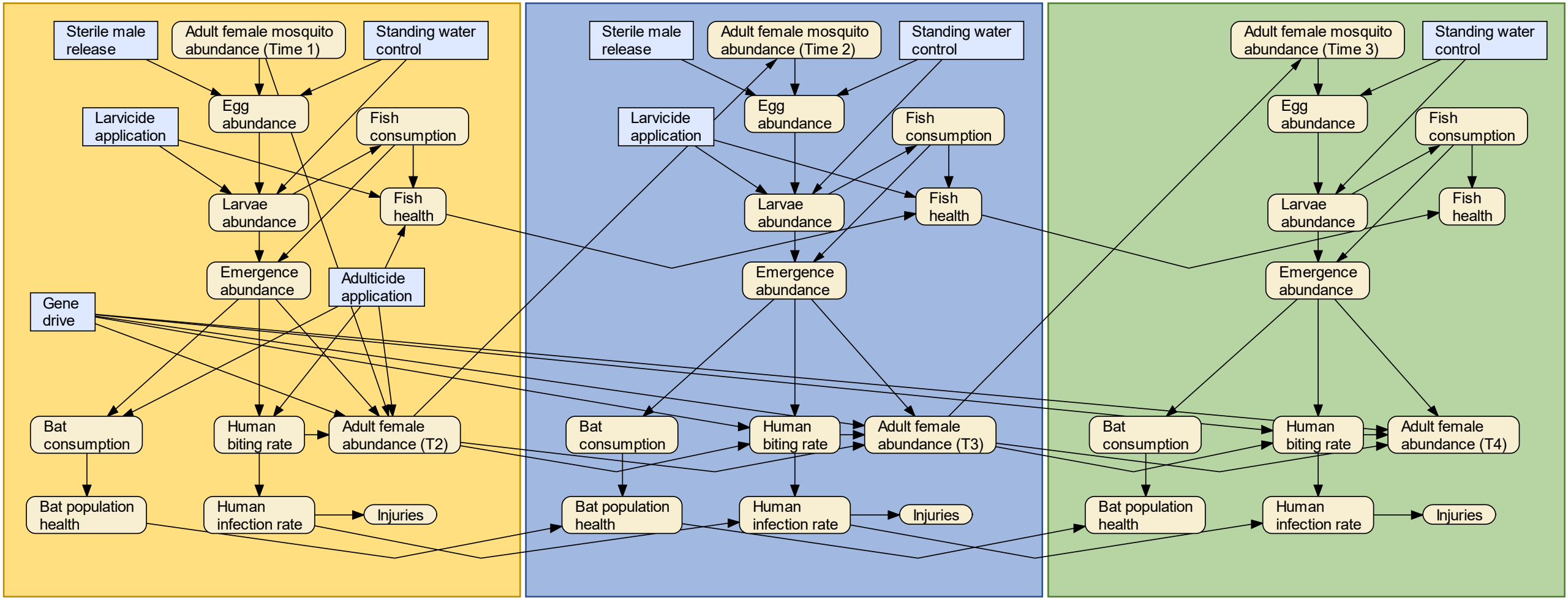
# Temporal application




Time 1

Time 2

# Temporal application




Time 1 Time 2 Time 3

# Inferences

- Quantitative
  - Potential (ecological and human) risks
  - Measurement uncertainty
  - Causal information (Korb et al. 2011)
  - Expected utility
  - Value of information
- Qualitative
  - Causal pathway analysis (Carriger et al. 2018)
  - Intervention design

Korb, KB, Nyberg, E & Hope, LR 2011, A new causal power theory. in PM Illari, F Russo & J Williamson (eds), *Causality in the Sciences.* Oxford University Press, Oxford UK, pp. 628 - 652.

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# Concluding remarks

- Bayesian networks are powerful modeling tools
- They are at the forefront of causal modeling
- Decision making and adaptive management relies on causal understanding
- Bayesian networks are an important asset for environmental management

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# Thank you!

Questions?