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Week 7:

Decisions under uncertainty part 2 + Risk

Instructor: Brielle K Thompson

Course: NAT_R 8001 Decision Analysis for Research and Management of Natural Resources

Begin with a few final presentations

1. Jake
2. Seth
3. Georgia
4. Madeline
5. Emma

Review of last week

- Background on types of uncertainties
  - Linguistic vs Epistemic uncertainties
- Learned about how sensitivity analysis, value of information, and adaptive management can be used in decisions where uncertainty may impede management
  - **Sensitivity analysis**
    - Perturbations to understand whether uncertainty is important to resolve
  - **Value of information**
    - Analysis to quantify the improvement of an outcome if uncertainty is resolved
  - **Adaptive management**
    - Formal process of “learning by doing” for repeated decisions

Today:
How do we make decisions under uncertainty & risk?

Working with uncertainty

Three Options:

1. Make decisions anyway
   Risk tools: e.g., Decision Trees, Utility Theory
2. Conduct research to reduce uncertainty
   Value of Information
3. Learn while managing
   Adaptive management

Risk = topic for this week!

last week

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Assessing risk

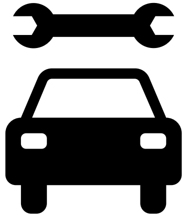
Risk = Chance of an unfavorable outcome

- Making a decision under uncertainty involves the decision maker's risk perception and attitude towards that risk
  - Perception: a subjective judgment of risk (cognitive)
  - Attitude: an individual's tendency to avoid or seek risks (behavioral)

Risk attitude examples

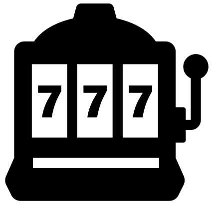
Risk-averse

- Buying insurance
- You would pay a sure amount to avoid a gamble with an average loss that is smaller than the sure payment. Why do it?



Risk-seeking

- Buying a lottery ticket
- You would pay a sure amount to enter a gamble with a smaller average return than the sure payment. Why do it?



Risk-neutral

- Choosing a standard investment with average returns (e.g., S&P 500)
- You would put an investment in something that on average will give you good returns

**risk averse investment = bonds/high-yield savings*

**risk seeking investment = individual stocks, crypto*

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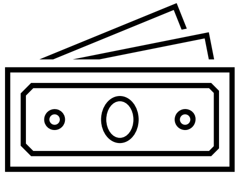
Risk attitude examples

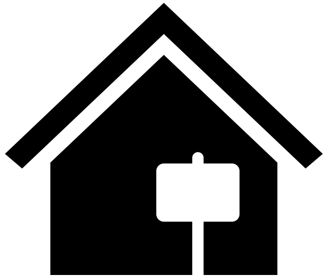
Risk-averse

- Accepting a salary instead of commission-based pay



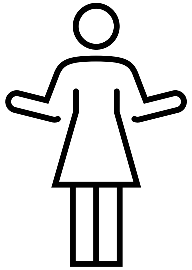
Risk-seeking

- Chooses commission-based pay hoping for a big payout despite risk



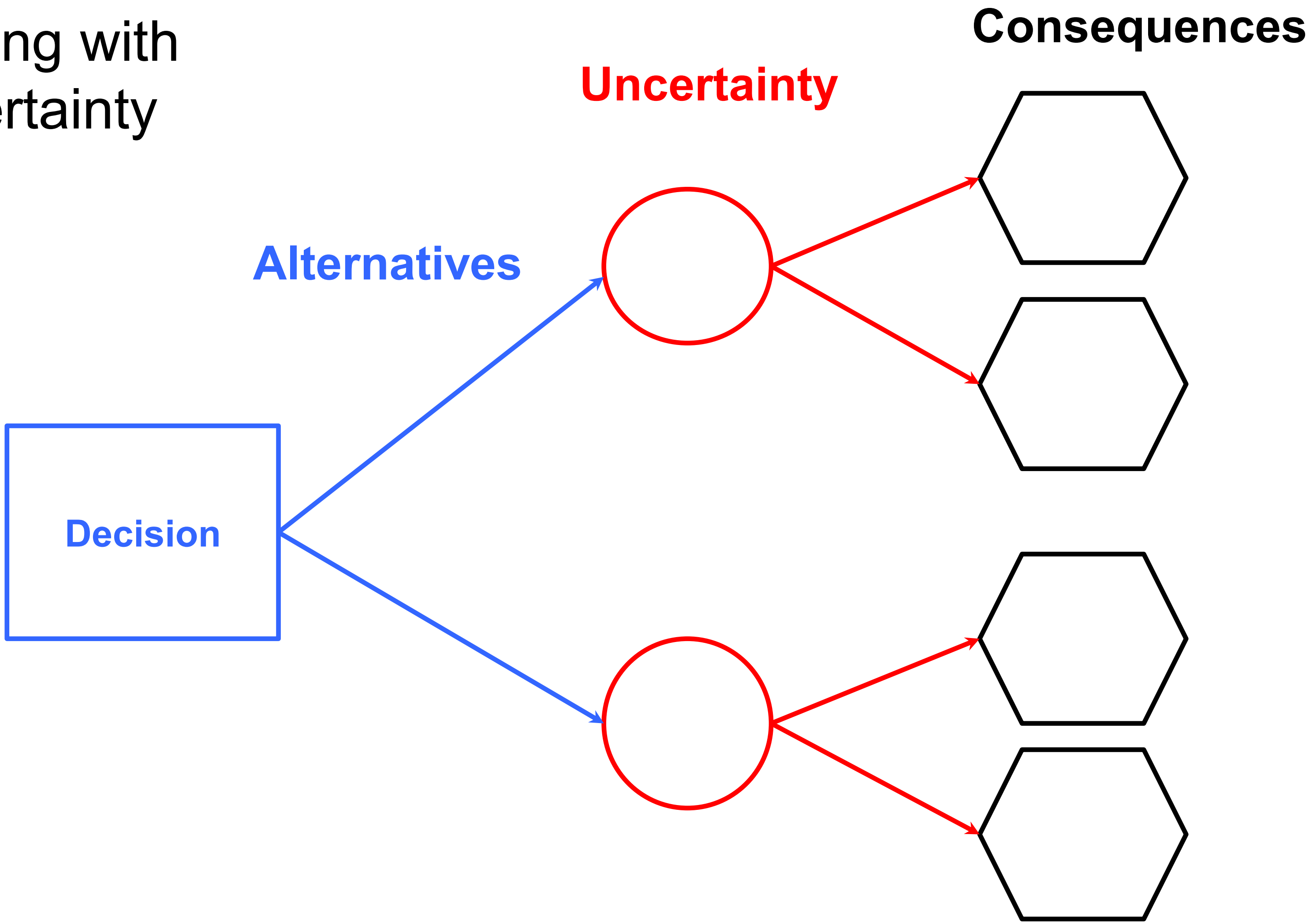
Risk-neutral:

- Indifferent between salary or commission as long as average payout is the same



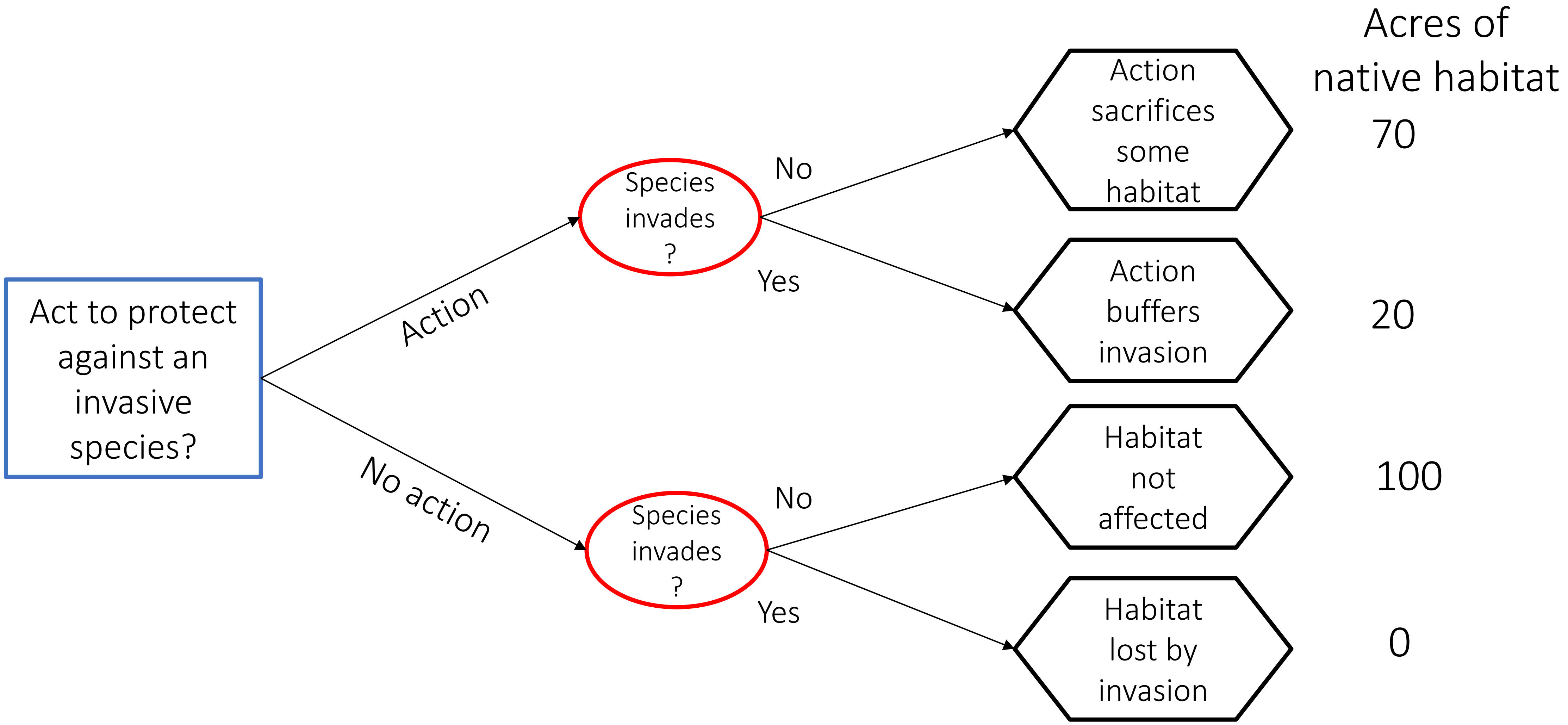
Back to decision trees:

A useful tool for dealing with uncertainty



Decision tree example:

Decision = Whether or not to create a no-habitat buffer around the refuge



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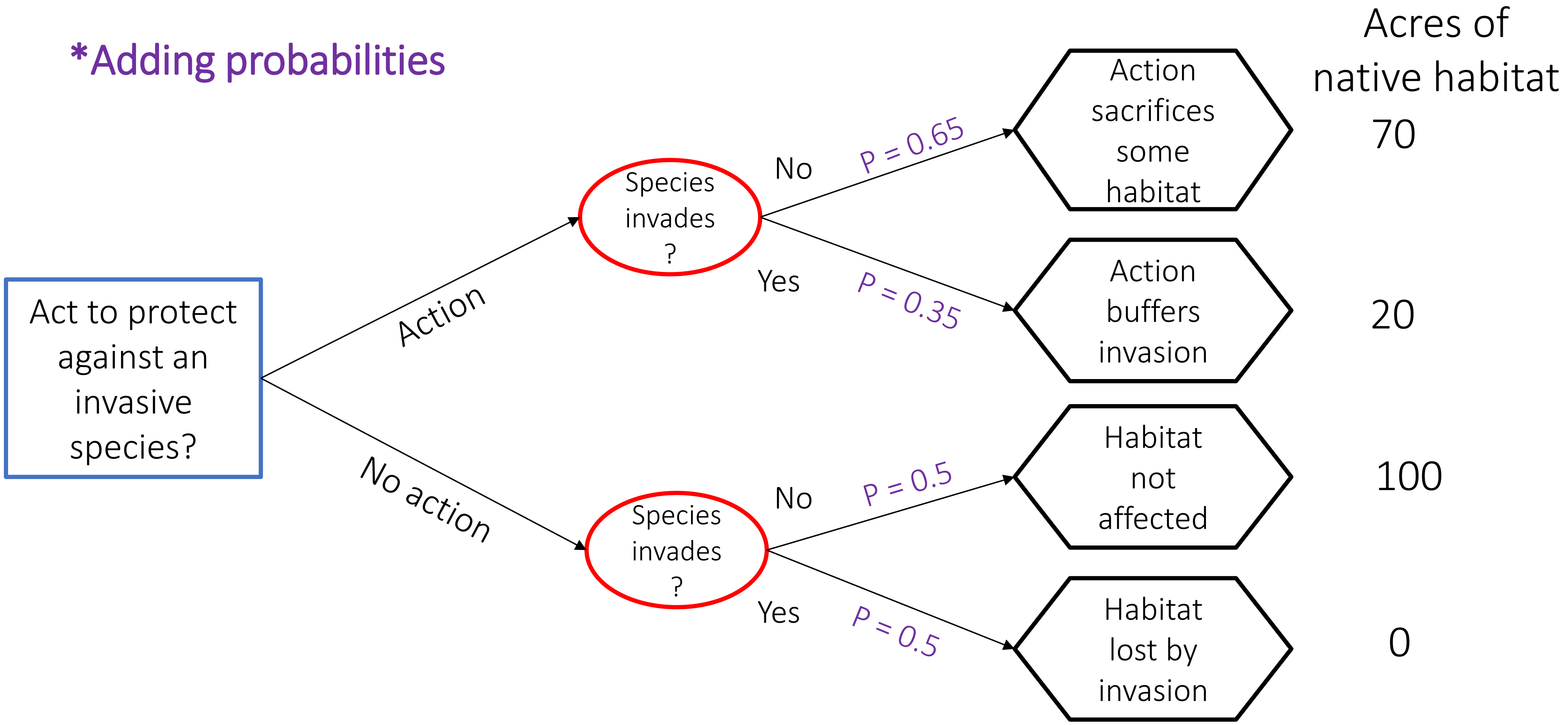
Decision tree example:

Decision = Whether or not to create a no-habitat buffer around the refuge

*Adding probabilities



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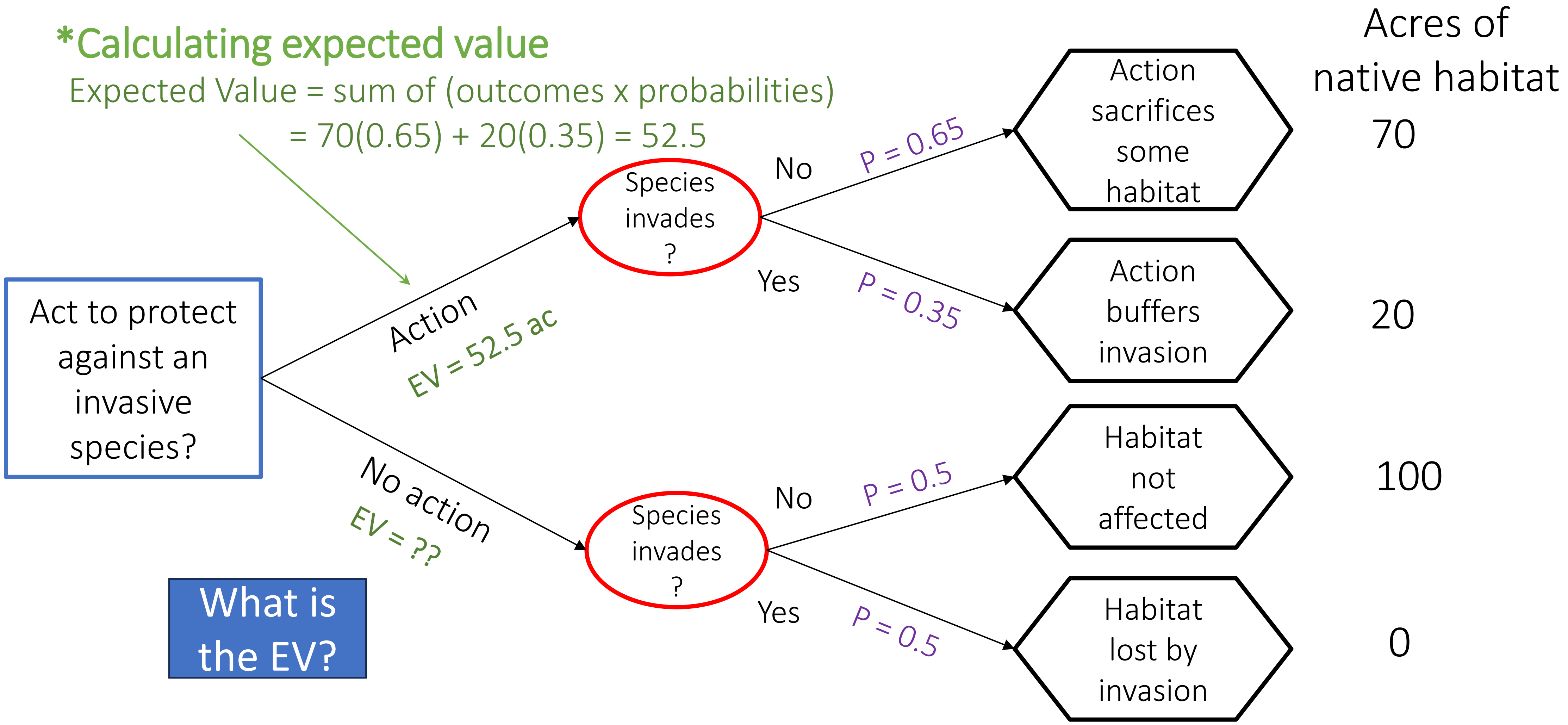

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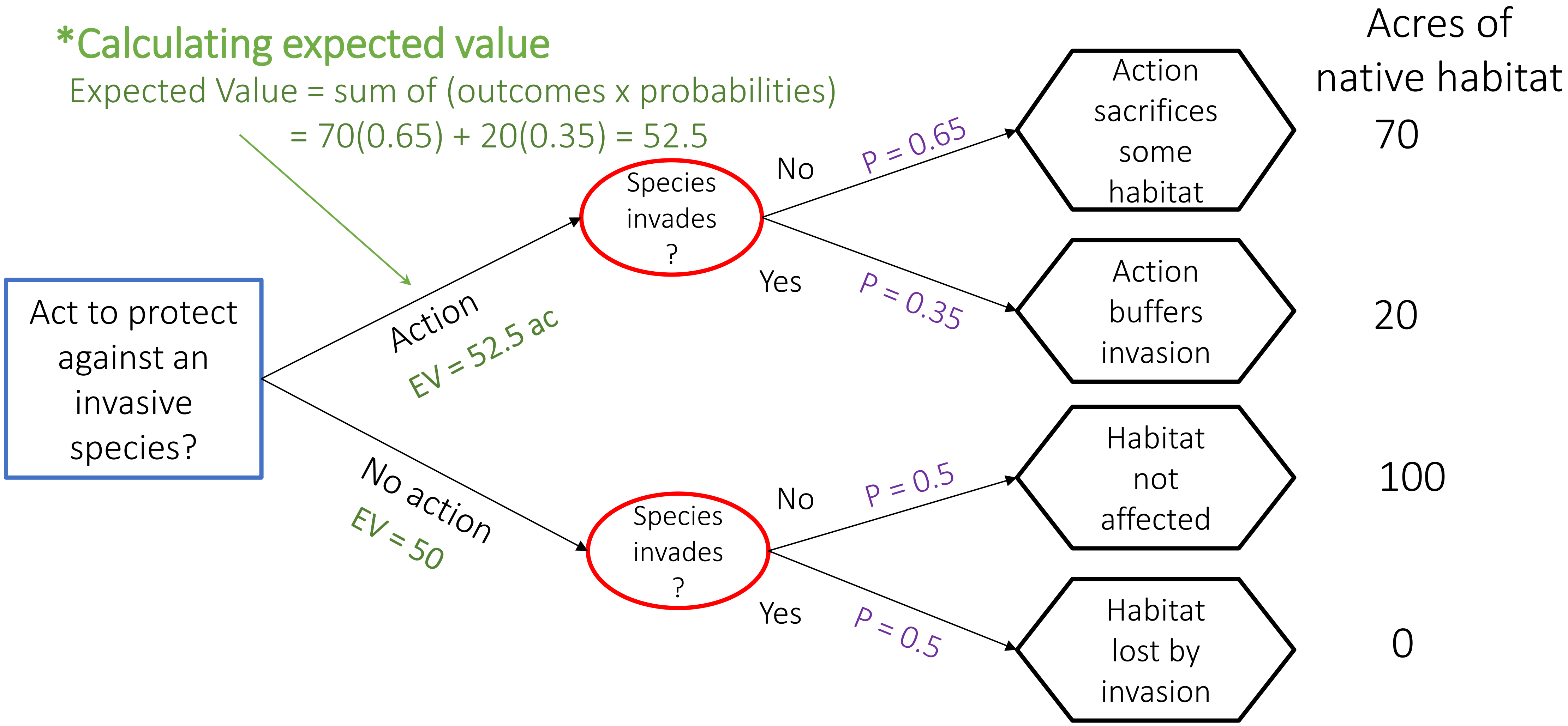

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Activity: Your risk attitude

- Consider the following game show with two options:
  1. **Take the gamble:** Select one of two doors and claim a prize. Behind one door is $1000 and behind the other is $0.
  2. **Take the sure thing:** Take $500 instead.

- Which option would you choose?

- Draw a tree to represent your options.

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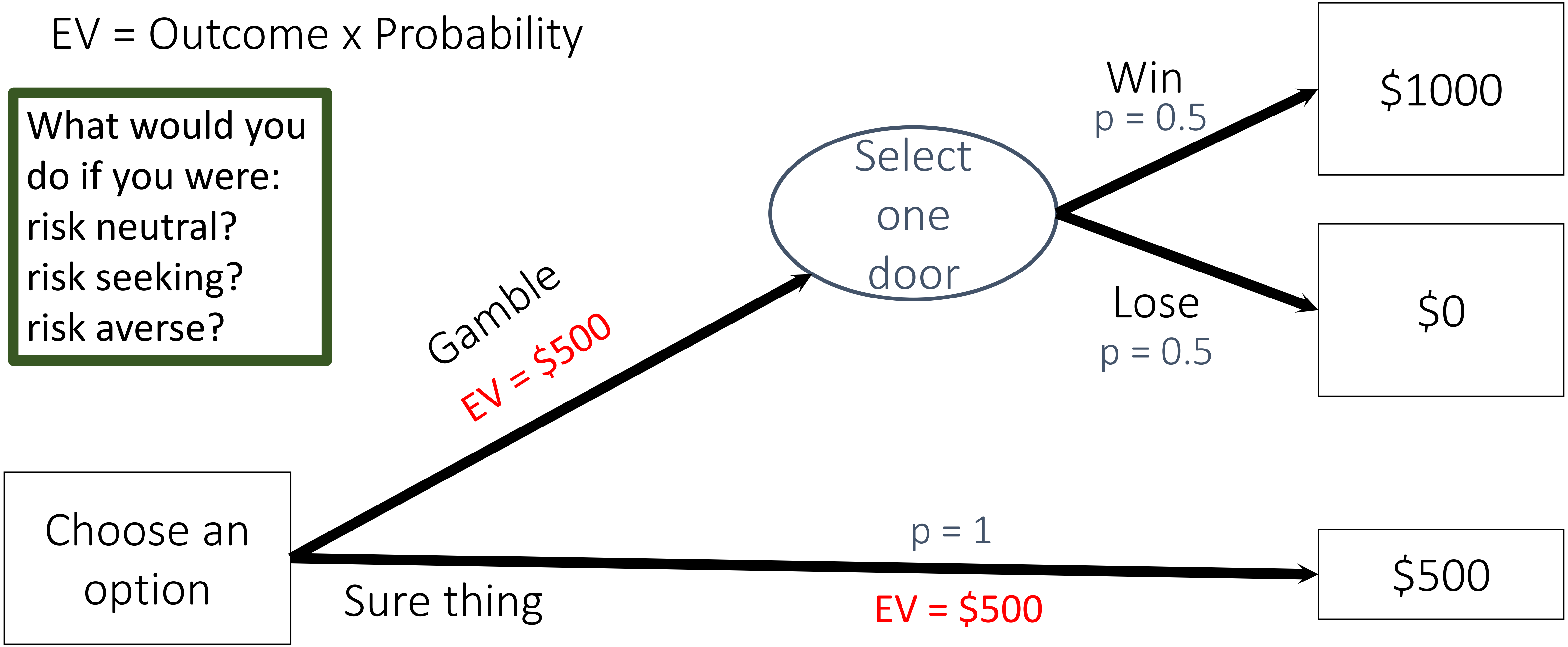
Activity: Your risk attitude

EV = Outcome x Probability

What would you do if you were:
risk neutral?
risk seeking?
risk averse?



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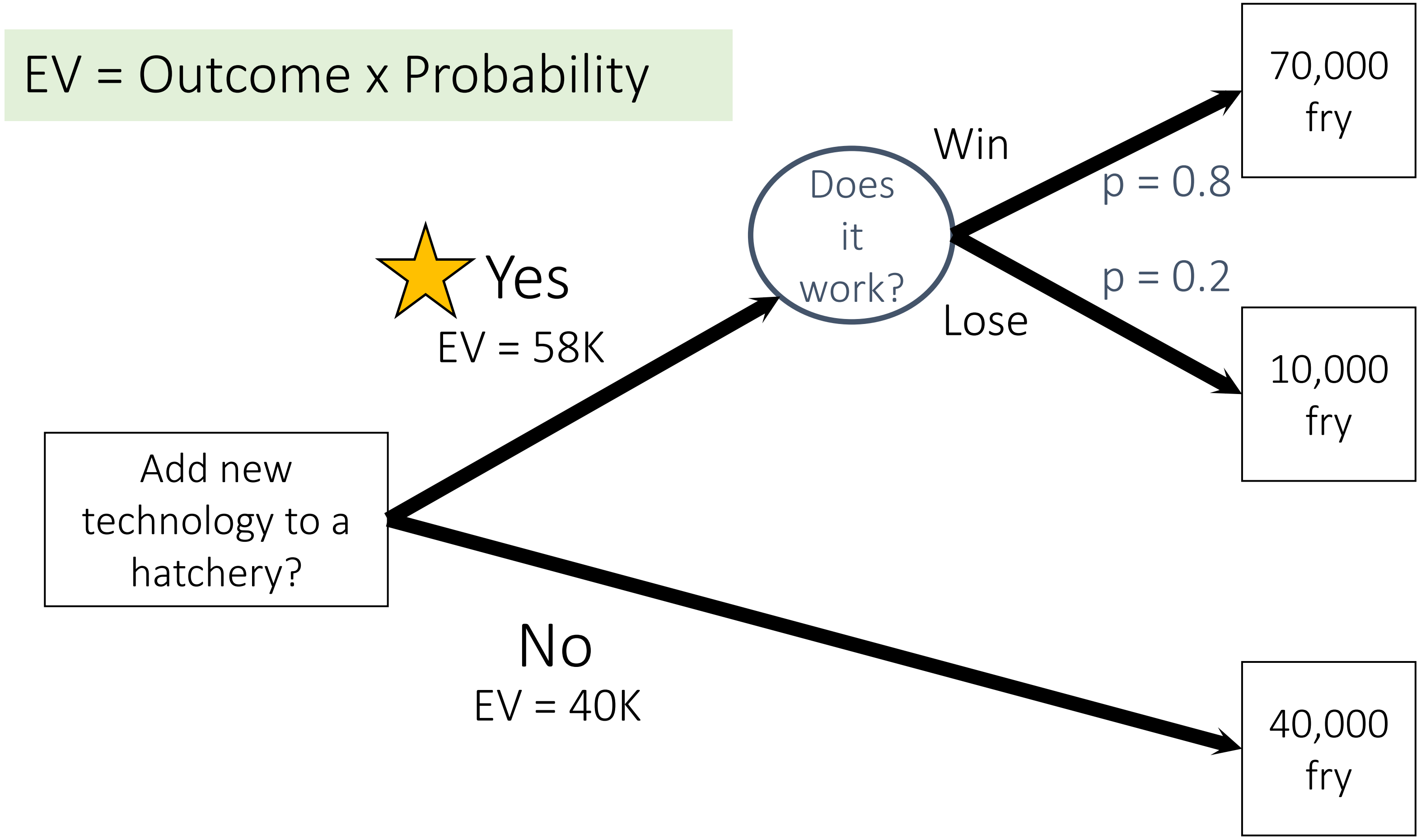
Approaches to risk:

- **Expected value (EV)**
  - Method = outcomes x probabilities
  - Solution = maximize EV

Approaches to risk example with EV:

- Should you adopt new technology to increase production of fry at a hatchery?



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Activity: Risk Discussion

- **Scenario 1**: You can either reintroduce an endangered species now with limited data or wait 3 years for better data but risk habitat degradation
  - Option A: Reintroduce now
  - Option B: Wait for data
- **Scenario 2**: You can invest in a new monitoring technology that might double detection rates, but it could fail completely. Or you can continue to use your current monitoring technology which produces worse detection but is consistent
  - Option A: Invest in new technology
  - Option B: Use current technology
- **Scenario 3**: You can implement a prescribed burn now to reduce wildfire risk, but weather conditions are marginal and could lead to unintended spread. Waiting for ideal conditions may delay the burn for months.
  - Option A: Burn now
  - Option B: Wait

For each scenario would you rather choose option A or B. Why?

Approaches to risk:

- Expected value (EV)
  - Method = outcomes x probabilities
  - Solution = maximize EV
- **Expected utility (EU)**
  - Method = Translate outcome onto a scale that incorporates risk attitude
  - Solution = Maximize EU

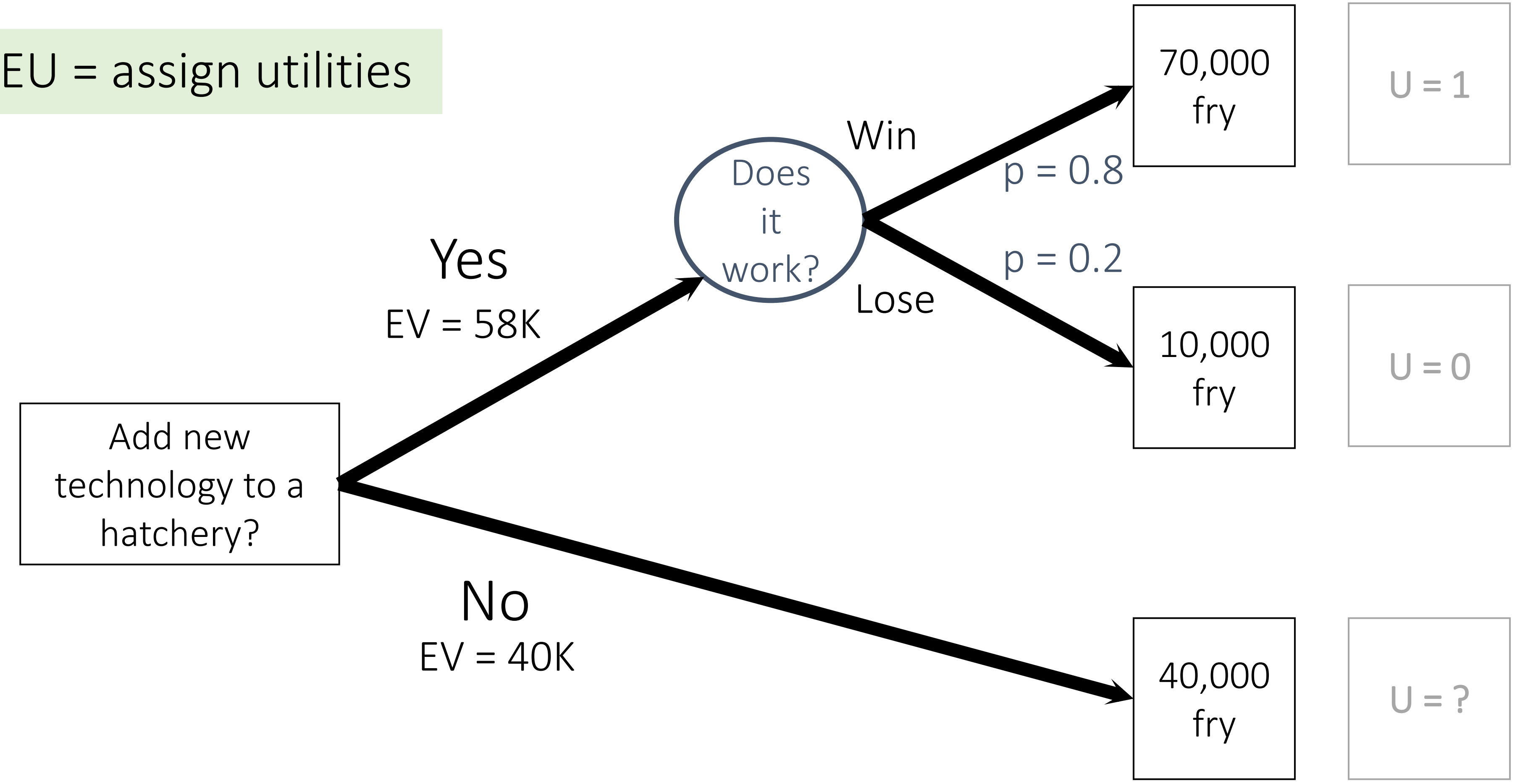
Expected utility:

- Useful for non-neutral risk attitudes
  - Convert outcome to a utility score to represent **attitude toward risk**
  - e.g., winning $1000 has U=1.0, $500 in pocket has U=0.6
- Can be applied to multiple objectives
- There are a variety of ways to determine utility

Approaches to risk example:

- Should you adopt new technology to increase production of fry at a hatchery?

EU = assign utilities



*Assign highest outcome utility of 1

*Assign lowest outcome utility of 0

?????
40K is halfway between 10K and 70K

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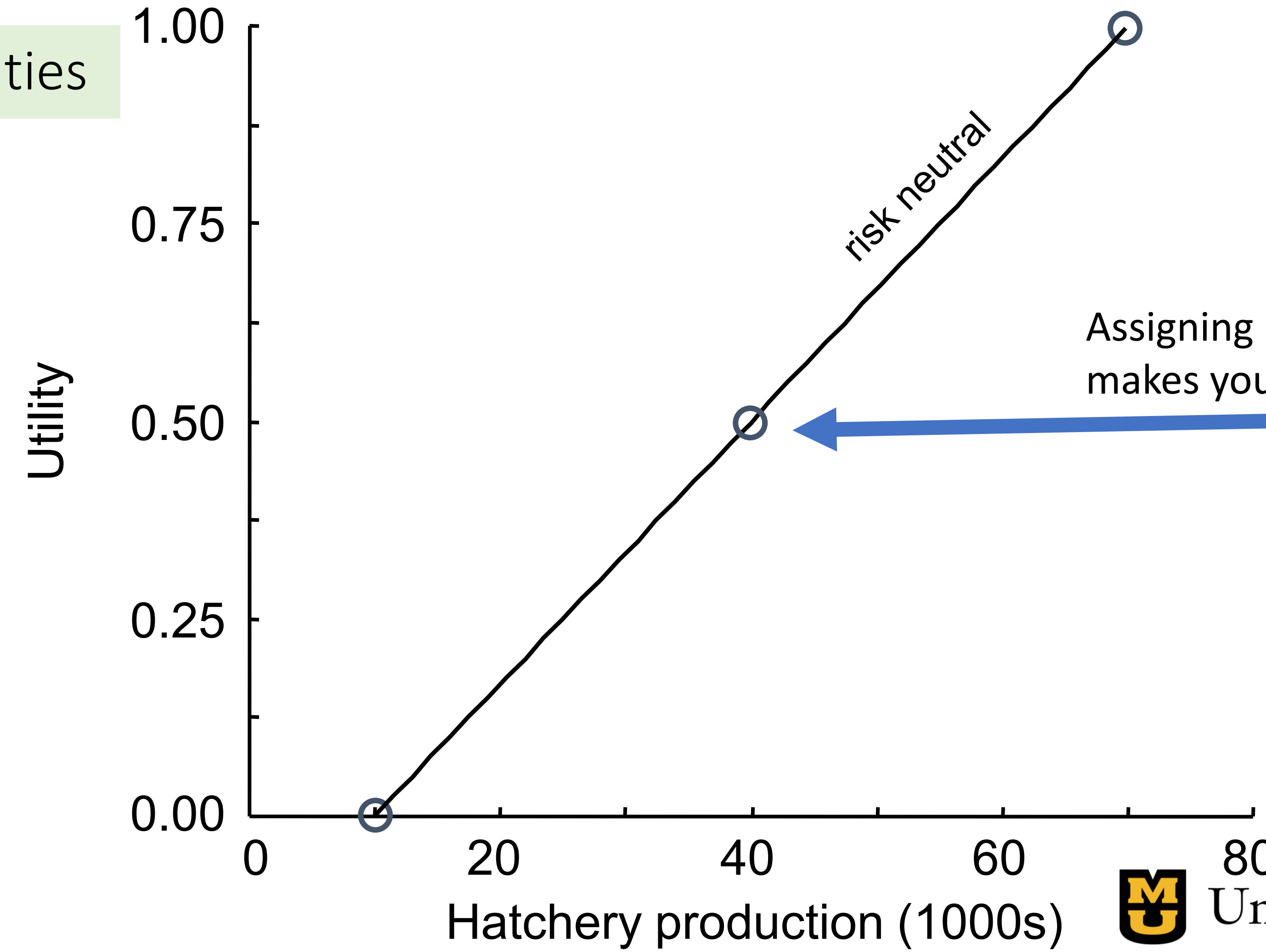
Approaches to risk example:

- Should you adopt new technology to increase production of fry at a hatchery?

EU = assign utilities

Utility of 40 K?????
40K is halfway between 10K and 70K



Assigning EU(40K) = 0.5 makes you risk neutral

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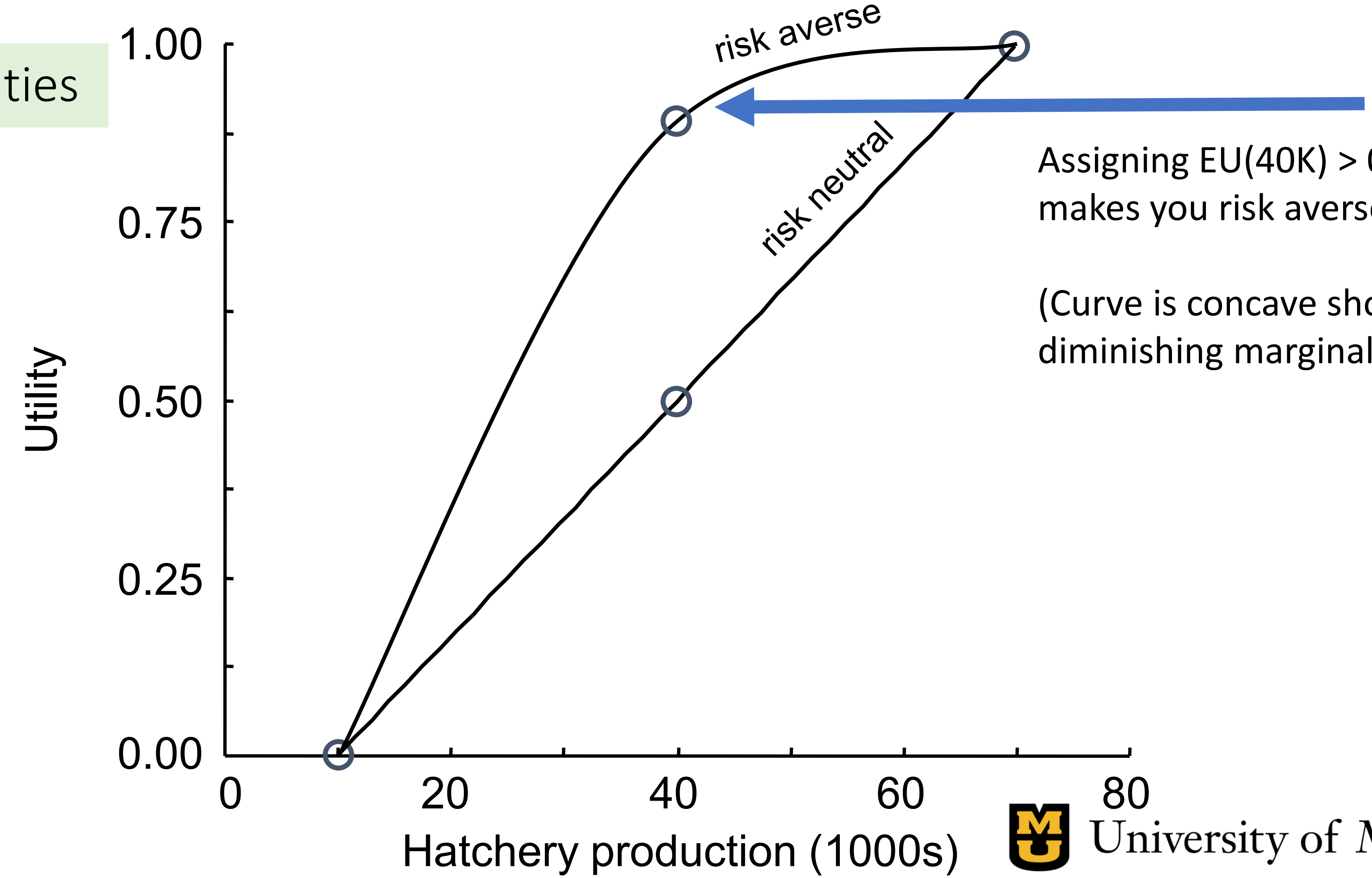
Approaches to risk example:

- Should you adopt new technology to increase production of fry at a hatchery?

EU = assign utilities

Utility of 40 K?????
40K is halfway between 10K and 70K



Assigning EU(40K) > 0.5 makes you risk averse

(Curve is concave showing diminishing marginal utility)

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Aside: diminishing utility

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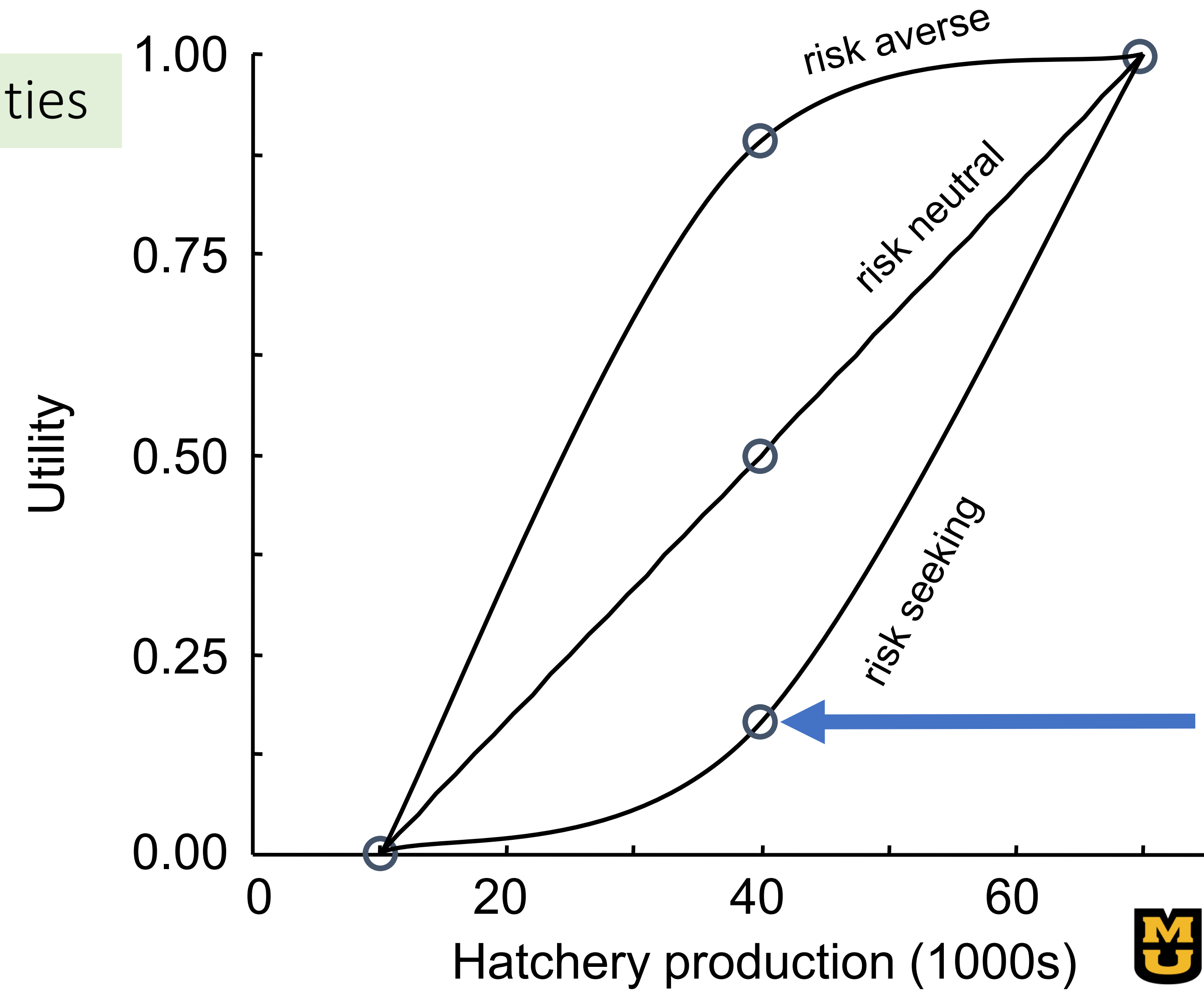
Approaches to risk example:

- Should you adopt new technology to increase production of fry at a hatchery?

EU = assign utilities

Utility of 40 K?????
40K is halfway between 10K and 70K



Assigning EU(40K) < 0.5 makes you risk seeking

(Curve is convex showing increasing marginal utility)

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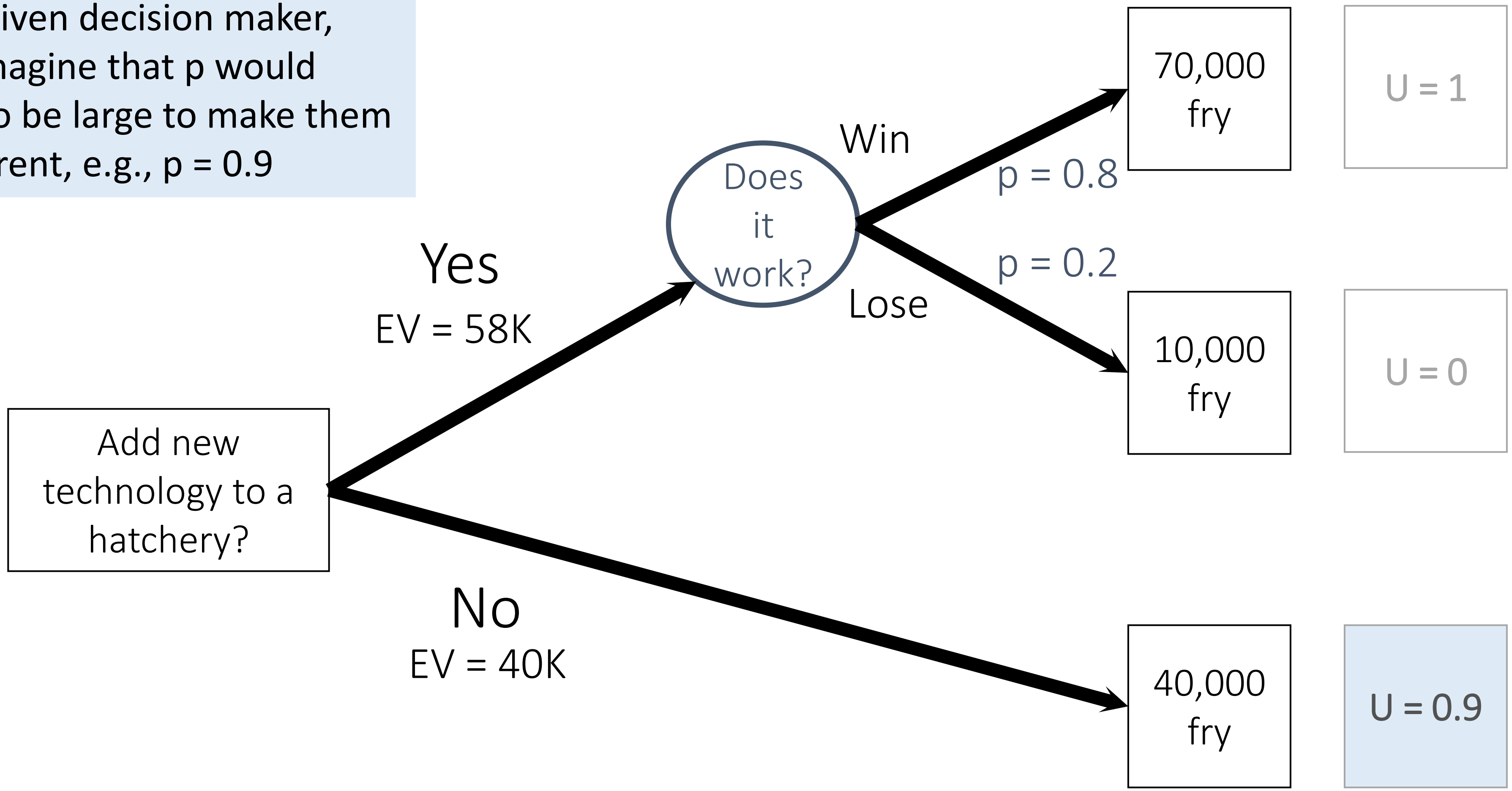
Using Gambles to Determine Utility

- Probability equivalence:
  - What probability of getting 70K fry vs 10K fry would you view as equivalent to a sure thing of getting 40K?
  - That is, at what probability of winning would you be indifferent to the gamble versus the sure thing?
  - We can show algebraically that this probability is equal to the utility of the sure thing

Developed by Sarah Converse, Brielle Thompson

Probability equivalence:

For a given decision maker, let's imagine that p would have to be large to make them indifferent, e.g., p = 0.9



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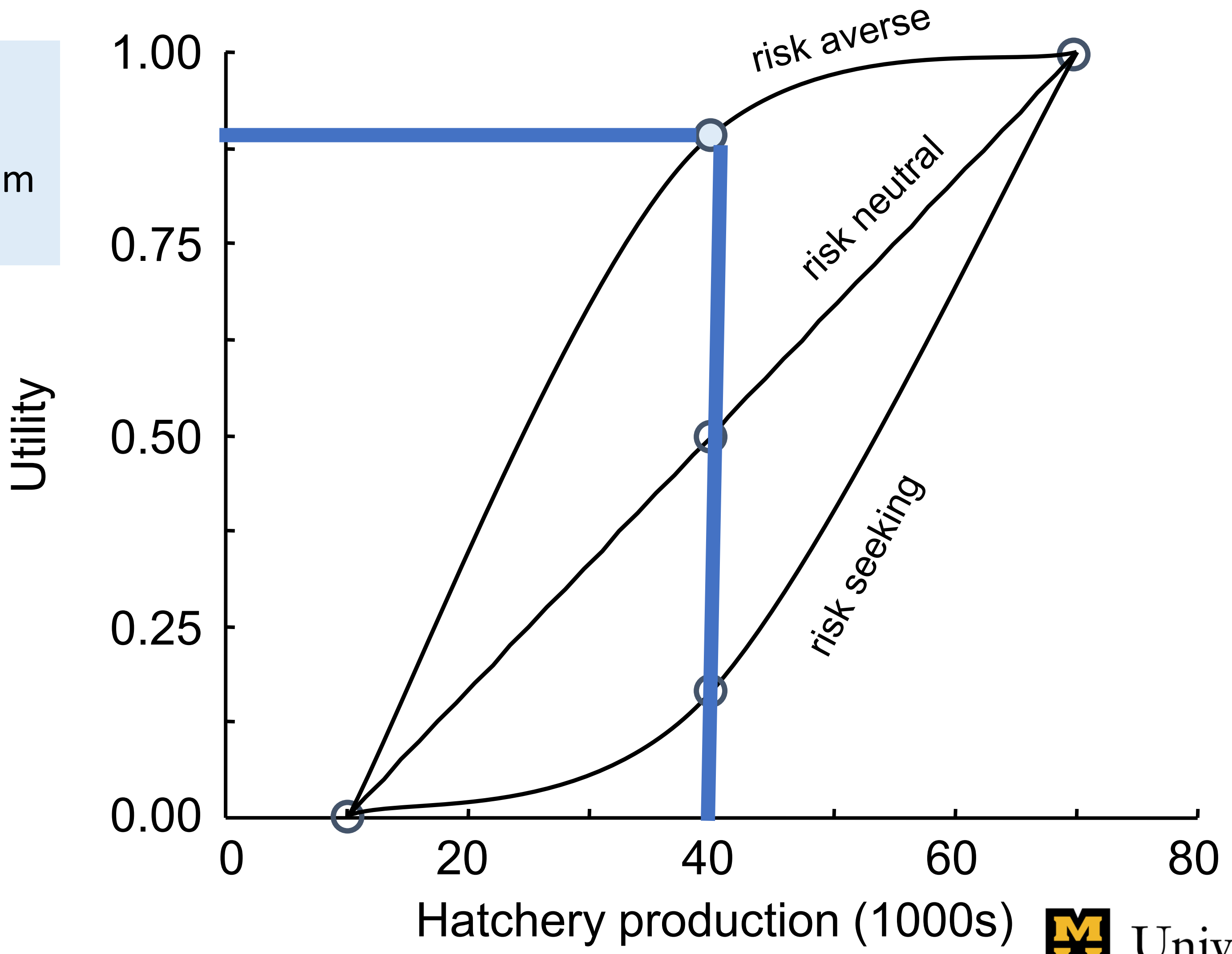
Probability equivalence:

For a given decision maker, let's imagine that p would have to be large to make them indifferent, e.g., p = 0.9

RISK AVERSE



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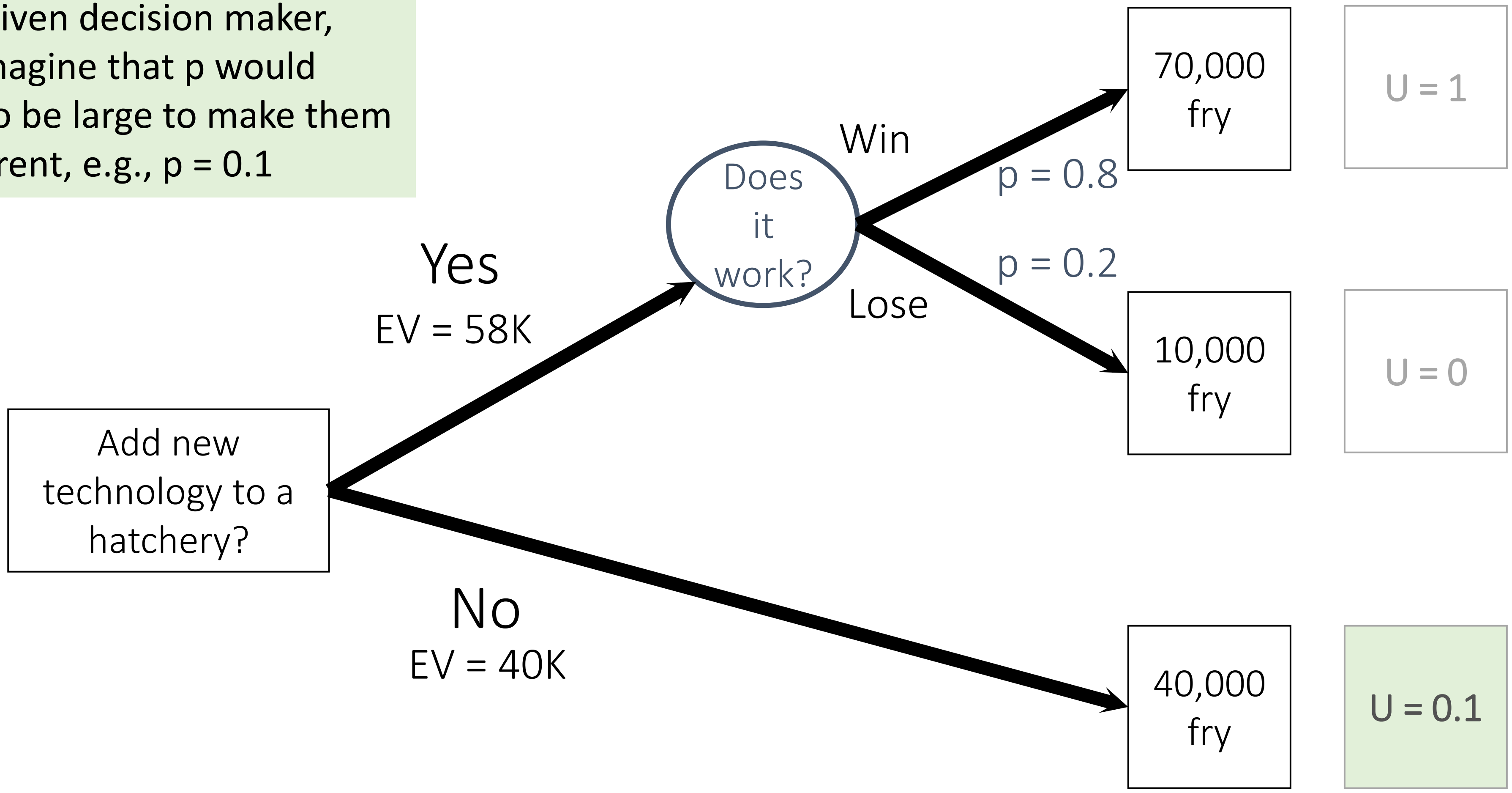
Probability equivalence:

For a given decision maker, let's imagine that p would have to be large to make them indifferent, e.g., p = 0.1



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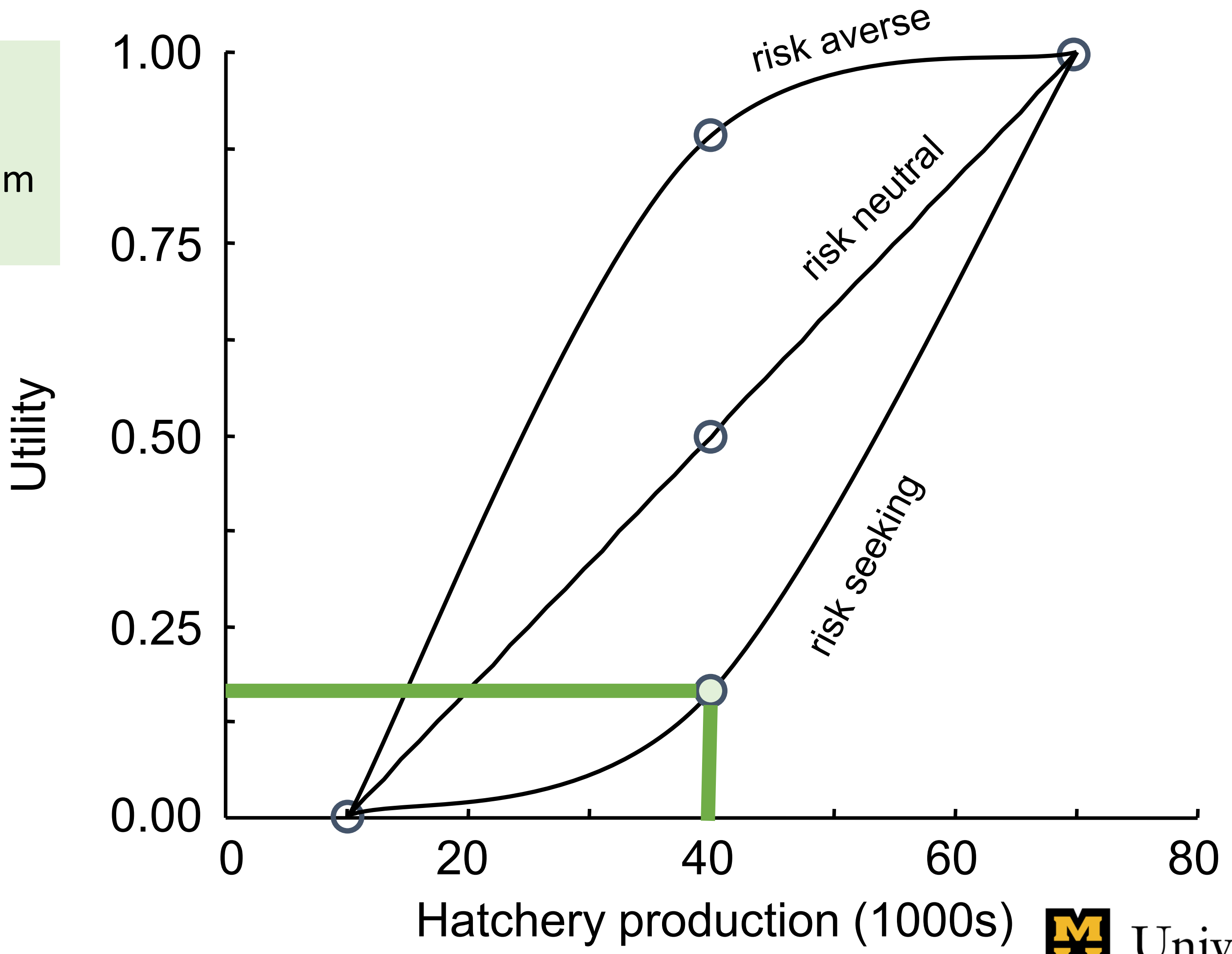
Probability equivalence:

For a given decision maker, let's imagine that p would have to be large to make them indifferent, e.g., p = 0.1

RISK SEEKING



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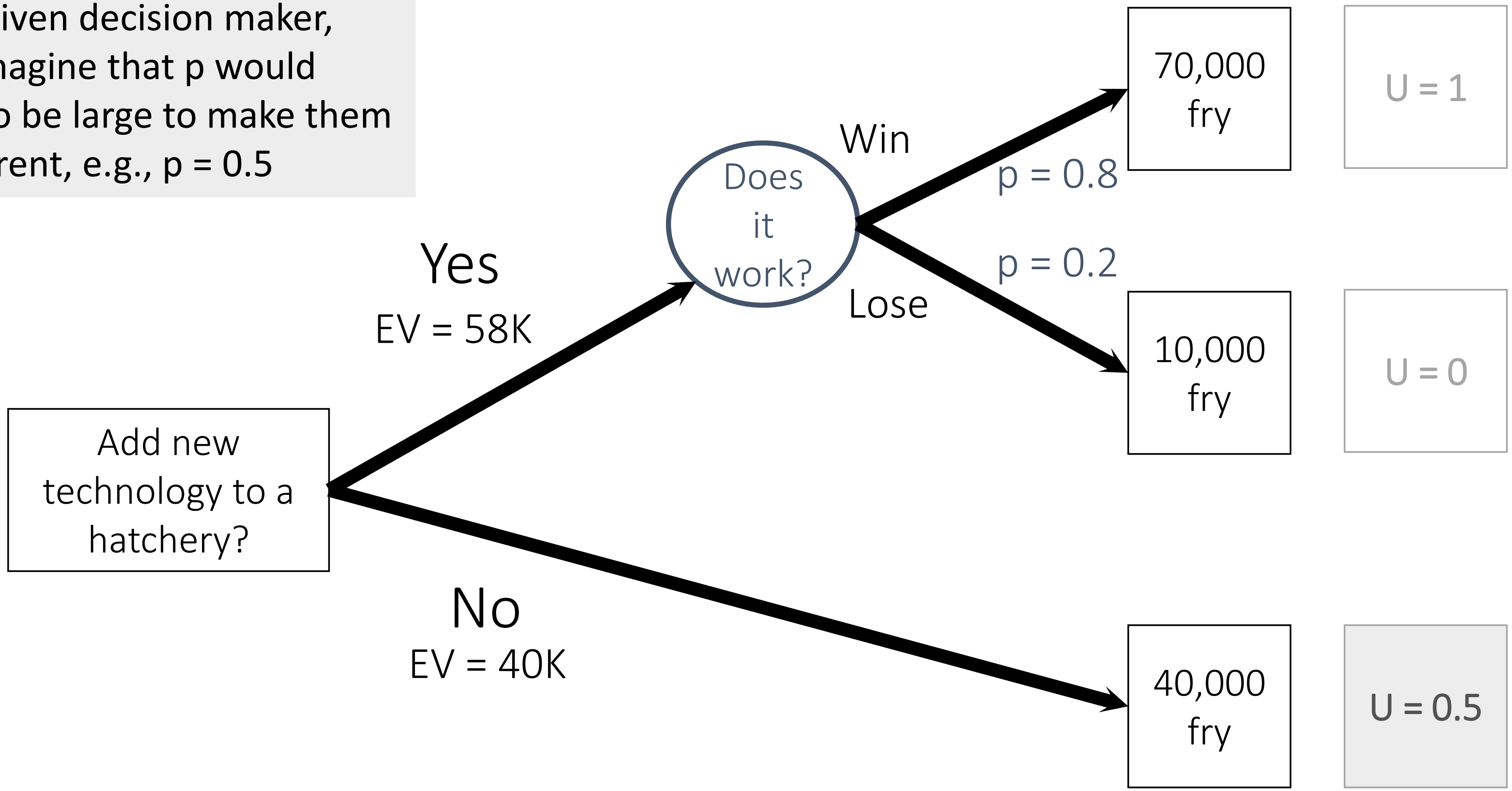
Probability equivalence:

For a given decision maker, let's imagine that p would have to be large to make them indifferent, e.g., p = 0.5



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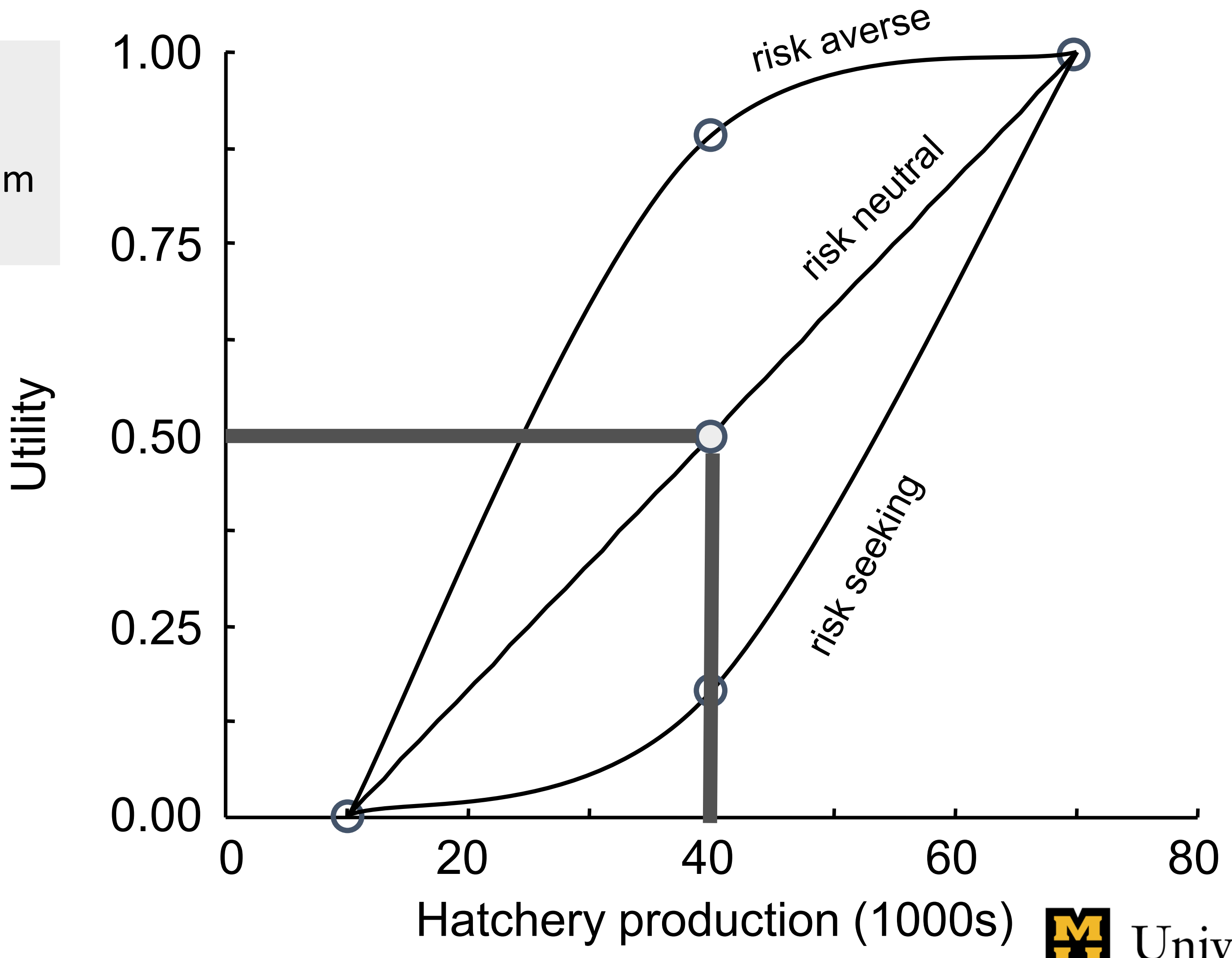
Probability equivalence:

For a given decision maker, let's imagine that p would have to be large to make them indifferent, e.g., p = 0.5

RISK NEUTRAL = EV



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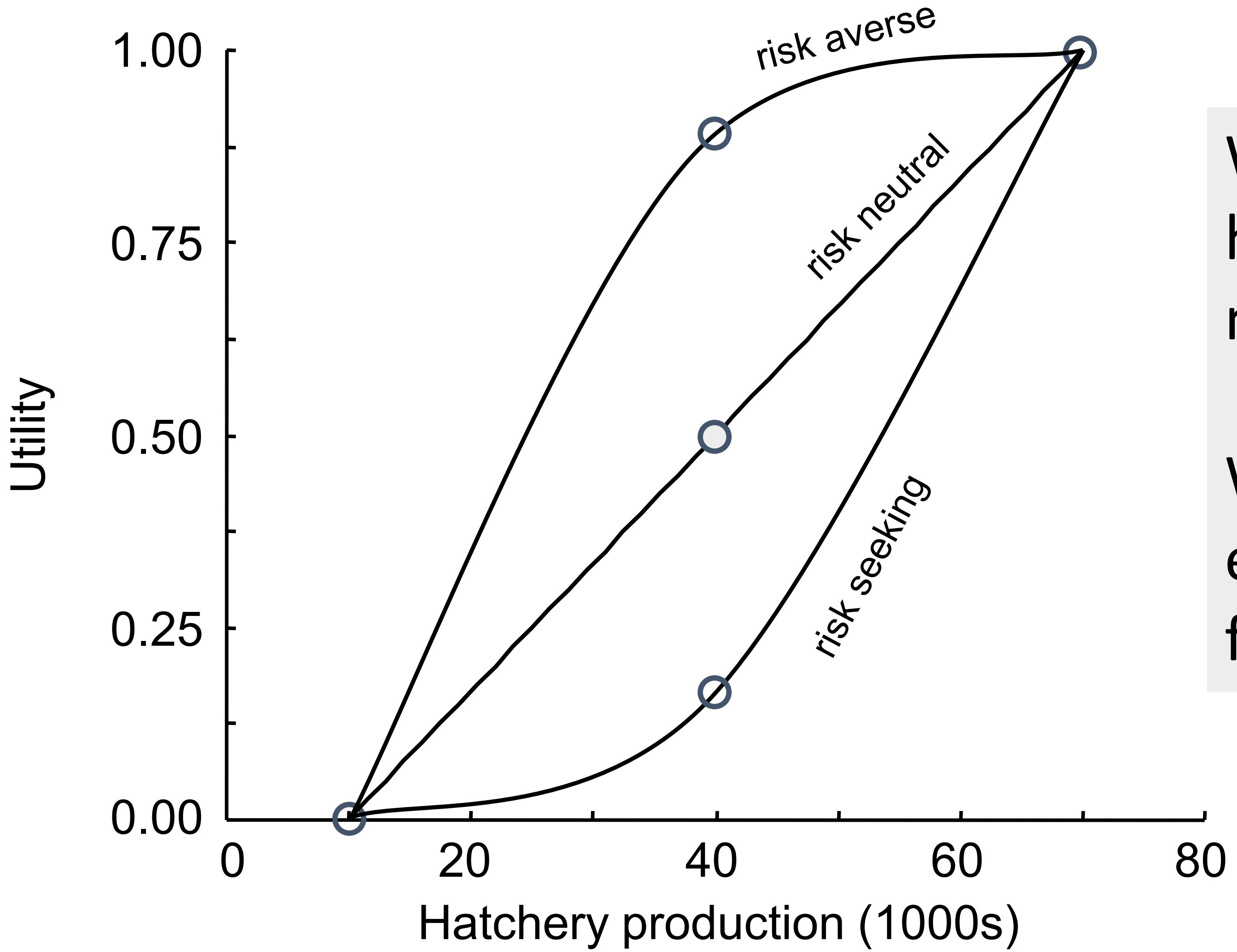
Probability equivalence:



We ask these gambles for more hatchery outcomes to obtain more points on the utility curves!

We can use models to create an equation for utility (Equation that fits the curve!).

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If you know the decision maker's risk attitude:

Assign utility functions:

Example:
1. Line = equal utility (risk neutral)
2. Logistic = diminishing marginal utility (risk averse)
3. Power/Exponential = increasing marginal utility (risk seeking)

Developed by Sarah Converse, Brielle Thompson

Brielle’s flight risk example:

Nor'easter weather forecast

NBC Boston

FIRST ALERT: Latest on nor'easter howling through New England

4 hours ago

CBS News

Nor'easter bringing whipping winds and heavy rain to Massachusetts as...

15 hours ago

WCVB

Video: Nor'easter conditions set to peak overnight

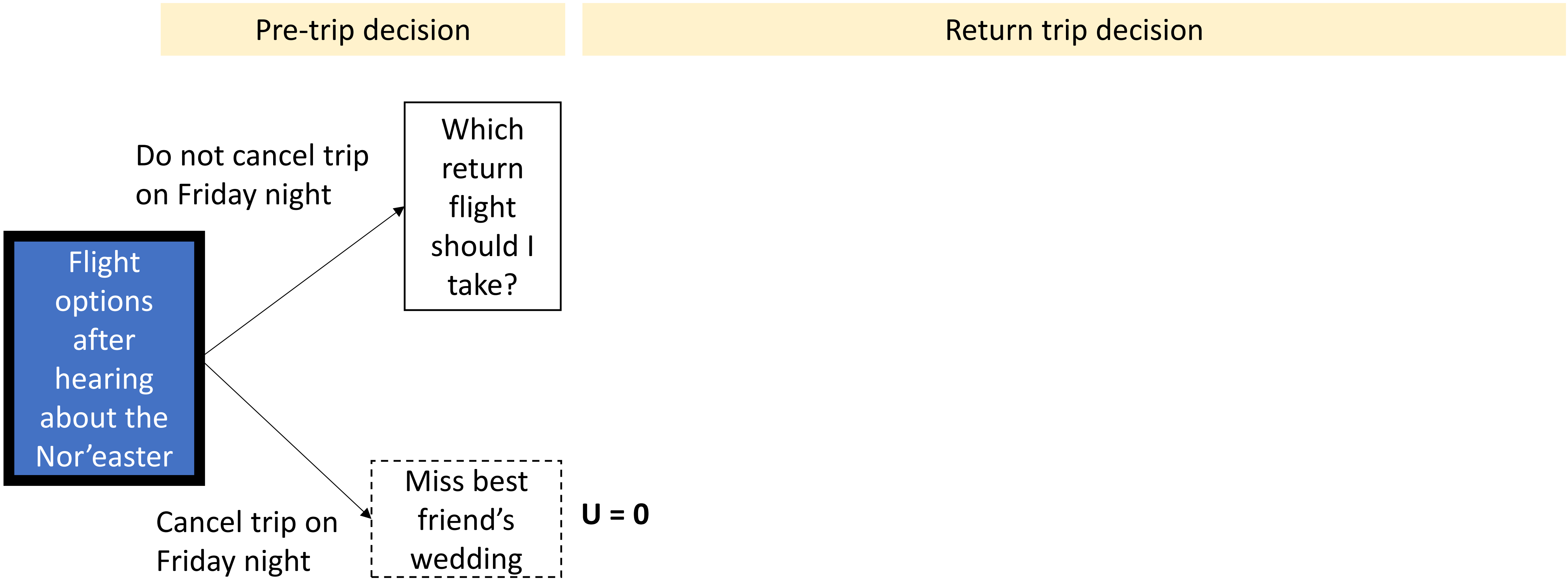
16 hours ago

The Boston Globe

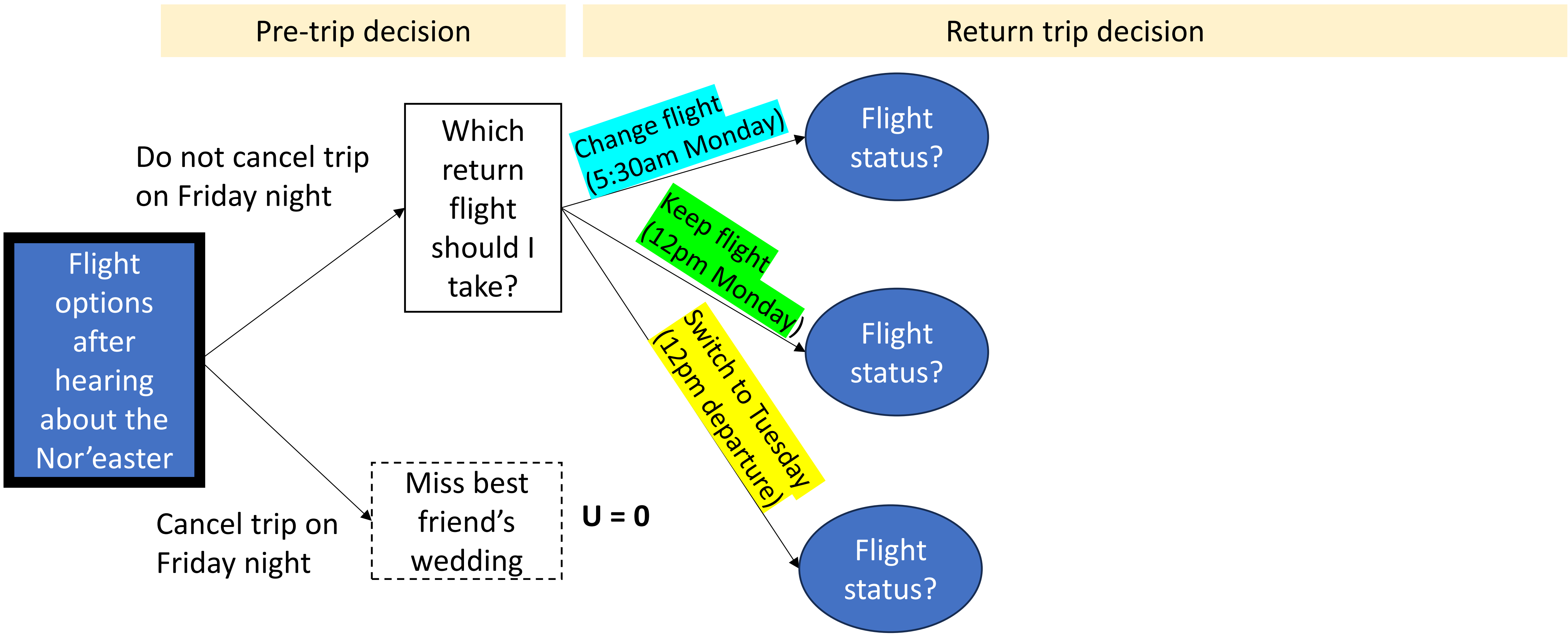
Beneath gray skies, Bostonians prepare for the first nor’easter of the season

18 hours ago

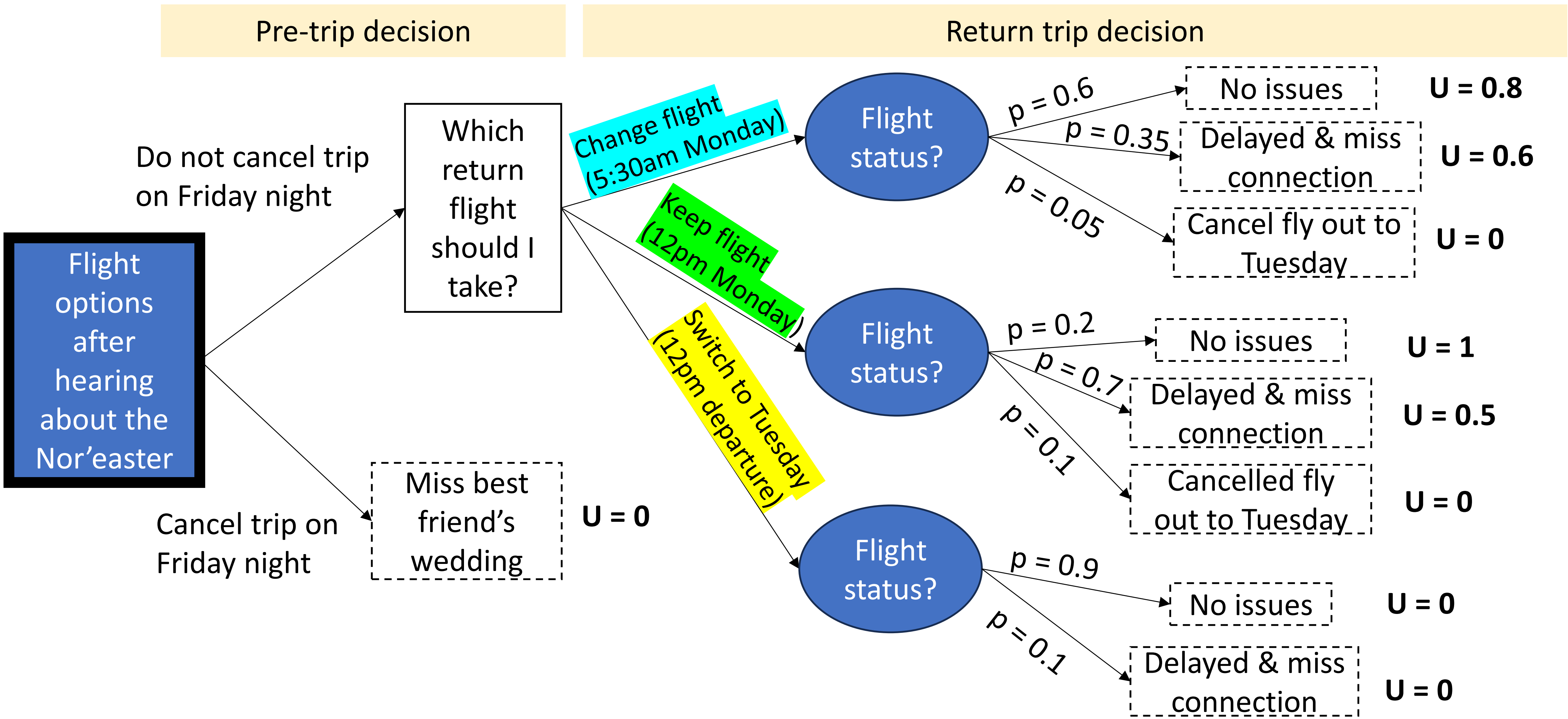
Brielle’s flight risk example:



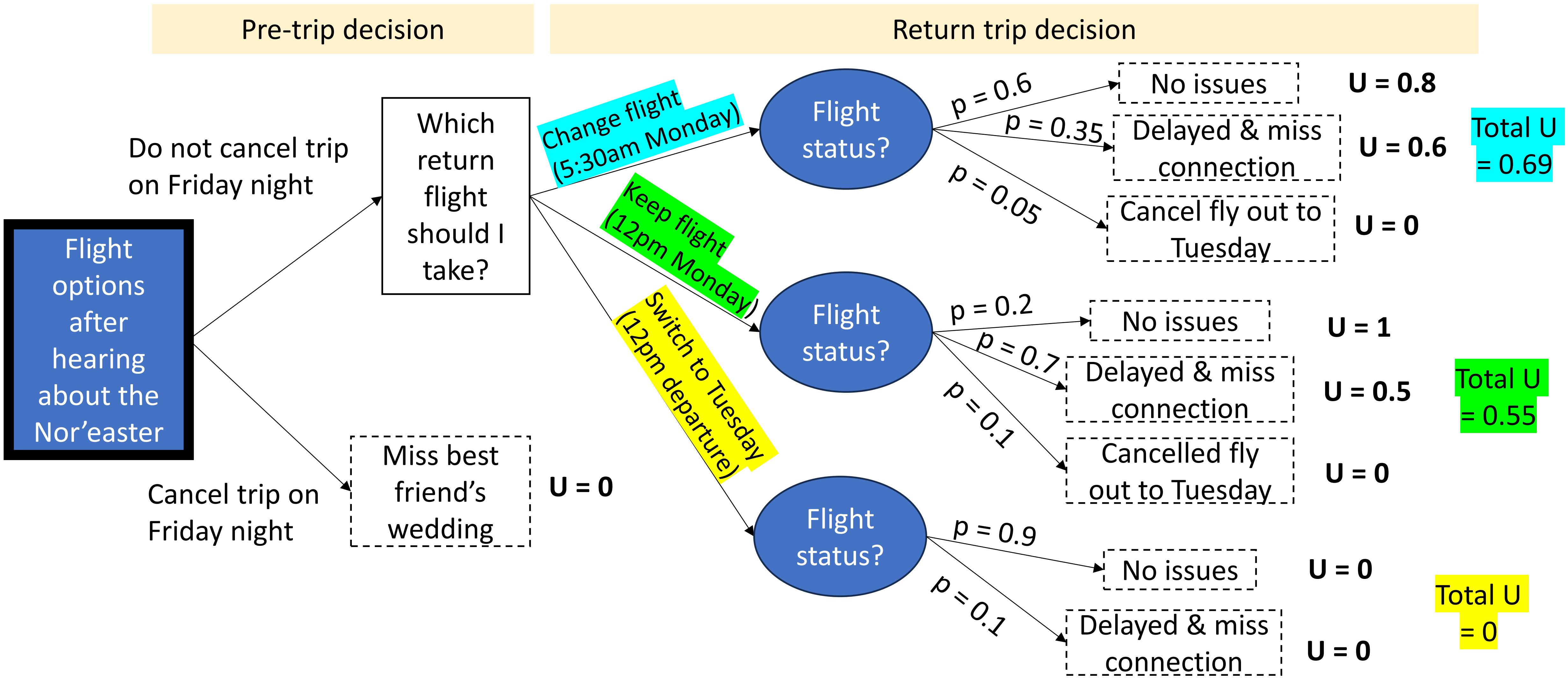
Brielle's flight risk example:



Brielle’s flight risk example:



Brielle's flight risk example:



Approaches to risk:

- Expected value (EV)
  - Method = outcomes x probabilities
  - Solution = maximize EV
- Expected utility (EU)
  - Method = Translate outcome onto a scale that incorporates risk attitude
  - Solution = Maximize EU
- **Other approaches**
  - Mini-max: Minimize risk of large losses
  - Robustness: Focus on attaining a minimum performance requirement over greatest range of uncertainty

Mini-max

- Minimize risk of large losses

Expected value: alternative that is best on average

Risk-neutral decision maker

Decision: route from St. Louis to Columbia

Expected value choice: take 70

Mini-max: alternative that minimizes worst possible outcome

Risk-averse decision maker

Decision: route from St. Louis to Columbia

Mini-max choice: avoid 70

Missouri

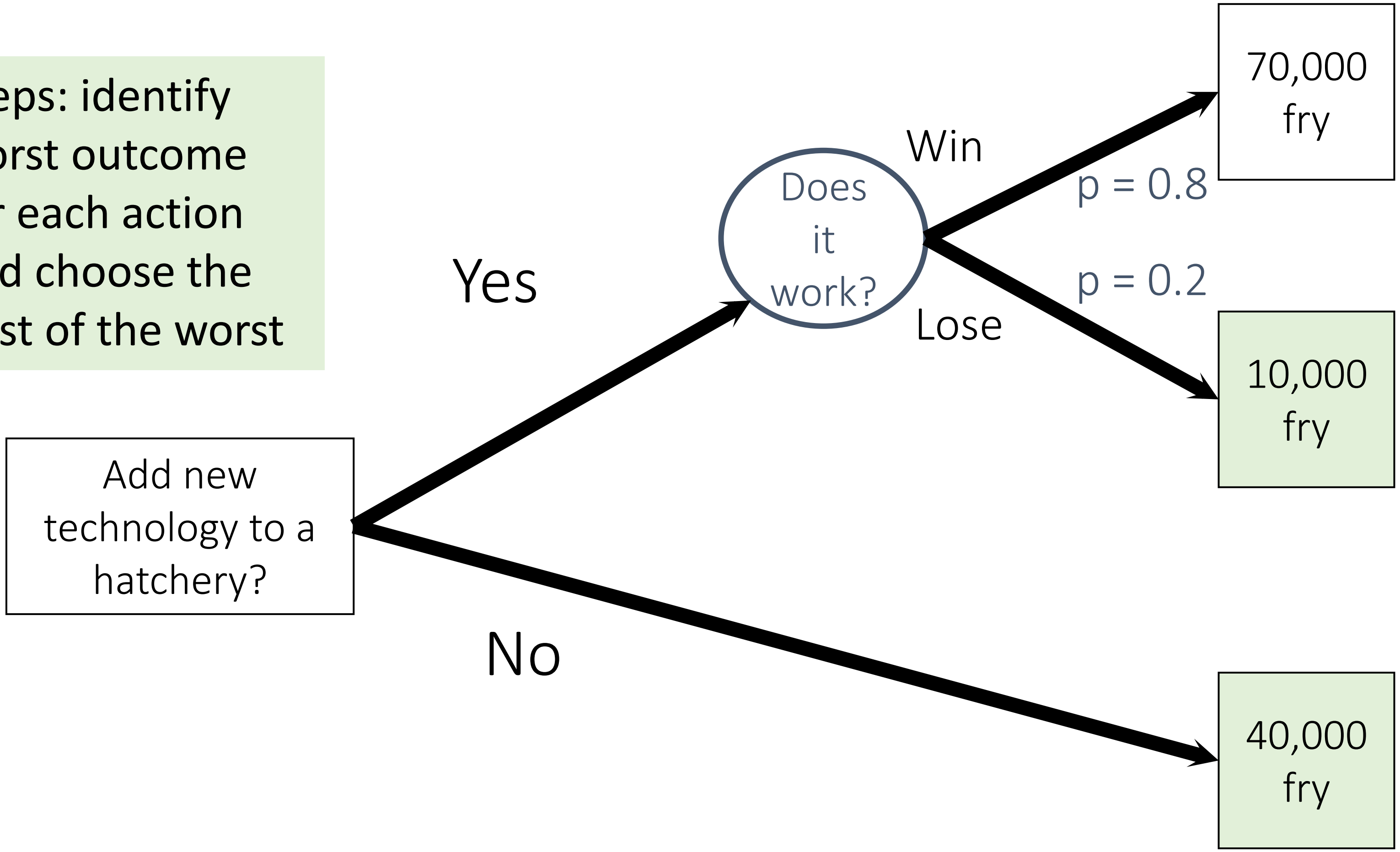
Developed by Brielle Thompson

Mini-max

- Minimize risk of large losses

Example: should you adopt new technology to increase production of fry at a hatchery?

Steps: identify worst outcome for each action and choose the best of the worst



best of the worst = 40K so we would NOT add new technology

Mini-max vs expected value example #1

Thompson, Olden, & Converse 2024 *NeoBiota*

Subset of the table: management alternatives to control invasive rusty crayfish

EV

Alternative management strategy, no. segments of removal effort	Objective (expected value)			Dominated by X Alternative
	Suppression (in millions)	Containment (%)	Prevention (in millions)	
Abundance, 8	**16.67 M**	85.7%	1.02 M	None
Growth, 8	18.34 M	83.1%	0.58 M	Downstream, 8
Edges, 8	17.92 M	85.1%	0.31 M	Downstream, 8
Downstream, 8	17.32 M	**81.4%**	**0.15 M**	None
Random, 8	16.93 M	85.7%	0.83 M	None

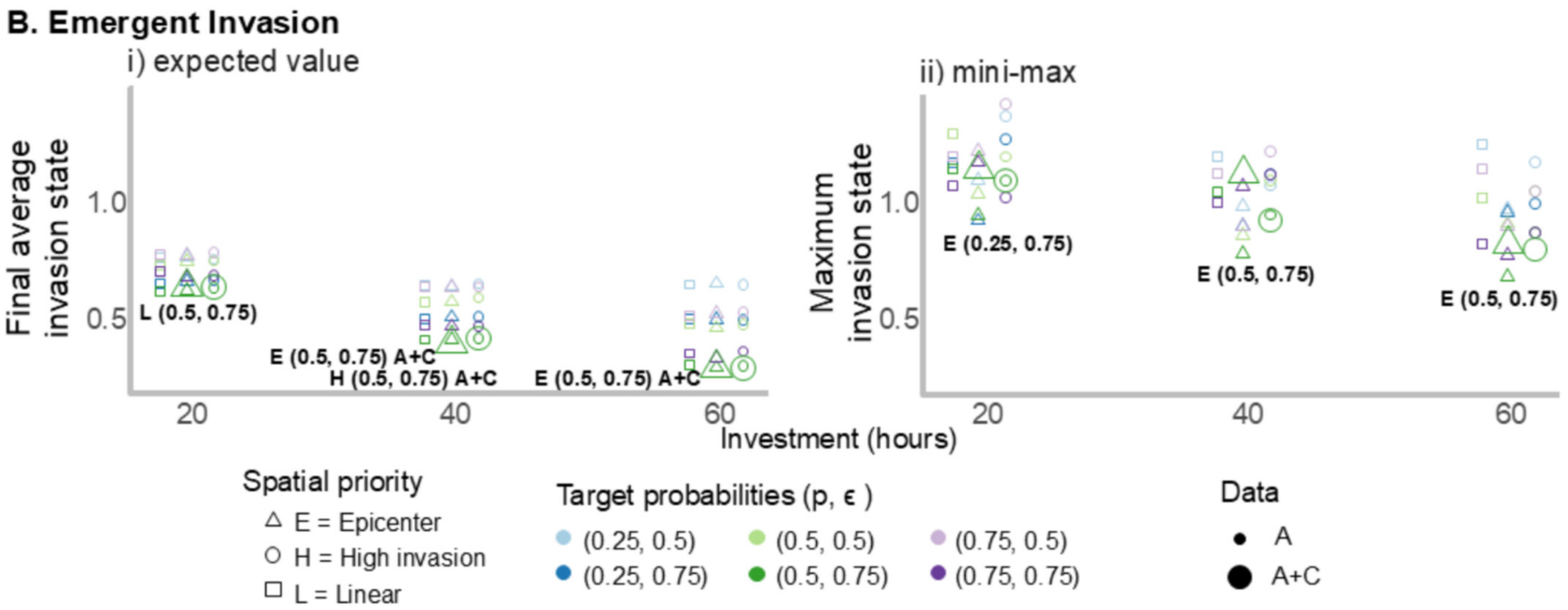
Mini-max

Alternative management strategy, no. segments of removal effort	Objective (minimum value)			Dominated by X Alternative
	Suppression (in millions)	Containment (%)	Prevention (in millions)	
Abundance, 8	72.32 M	100%	4.53 M	Edges, 8 & Downstream, 8
Growth, 8	**69.91 M**	100%	5.00 M	None
Edges, 8	70.08 M	100%	2.10 M	None
Downstream, 8	71.49 M	100%	**1.70 M**	None
Random, 8	73.30 M	100%	5.72 M	All

Mini-max vs expected value example #2

Management outcomes for invasive flowering rush

[Thompson et al. 2025]



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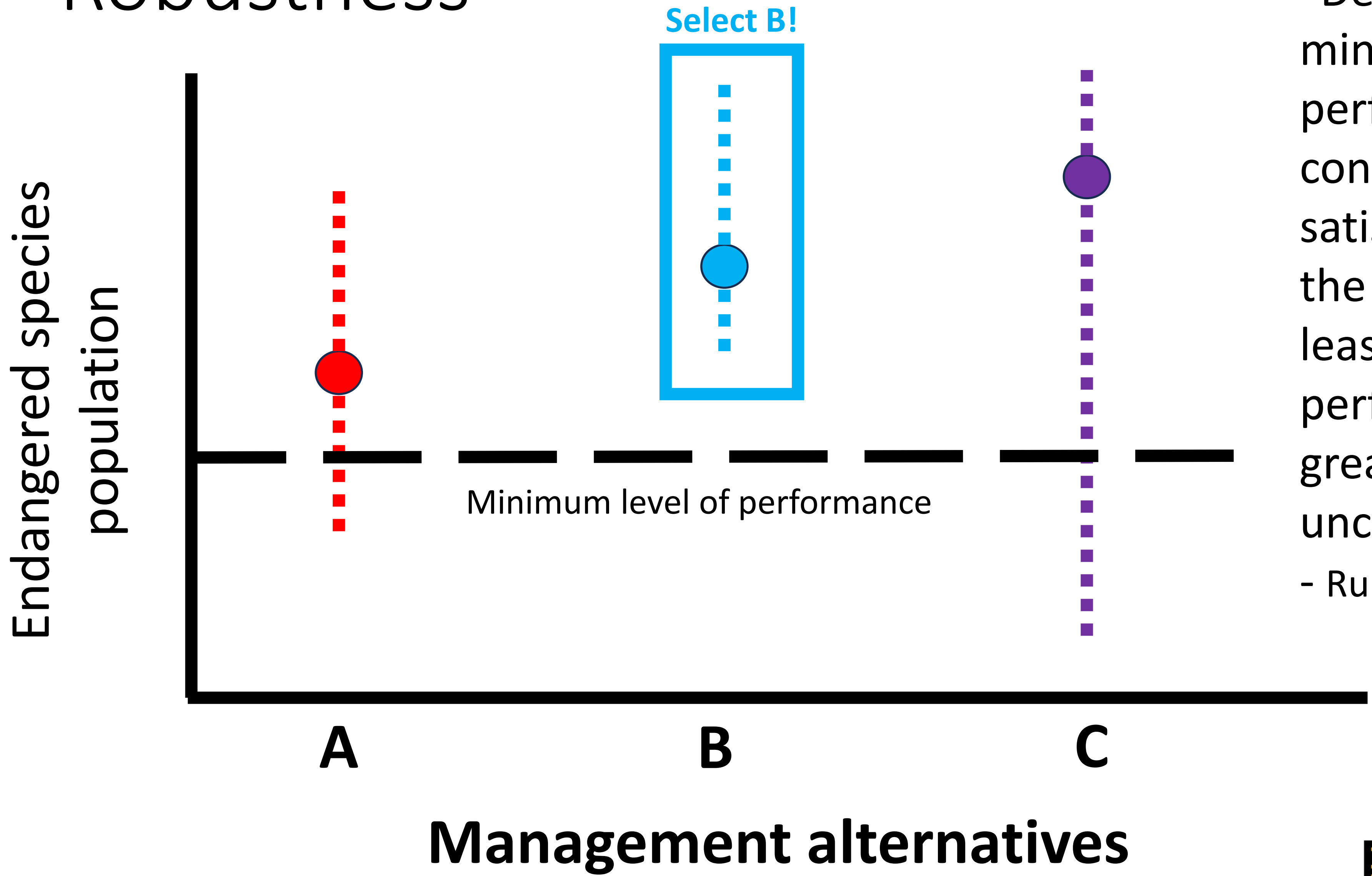
Robustness

- Robust-satisficing: focus on attaining a minimum performance requirement over greatest range of uncertainty
  - "Decision maker defines a minimum level of performance they consider to be satisfactory and chooses the option that ensures at least that level of performance over the greatest range of uncertainty"
    - *Ben-Haim 2006

Robustness



"Decision maker defines a minimum level of performance they consider to be satisfactory and chooses the option that ensures at least that level of performance over the greatest range of uncertainty"

- Runge et al. 2020 Ch 13

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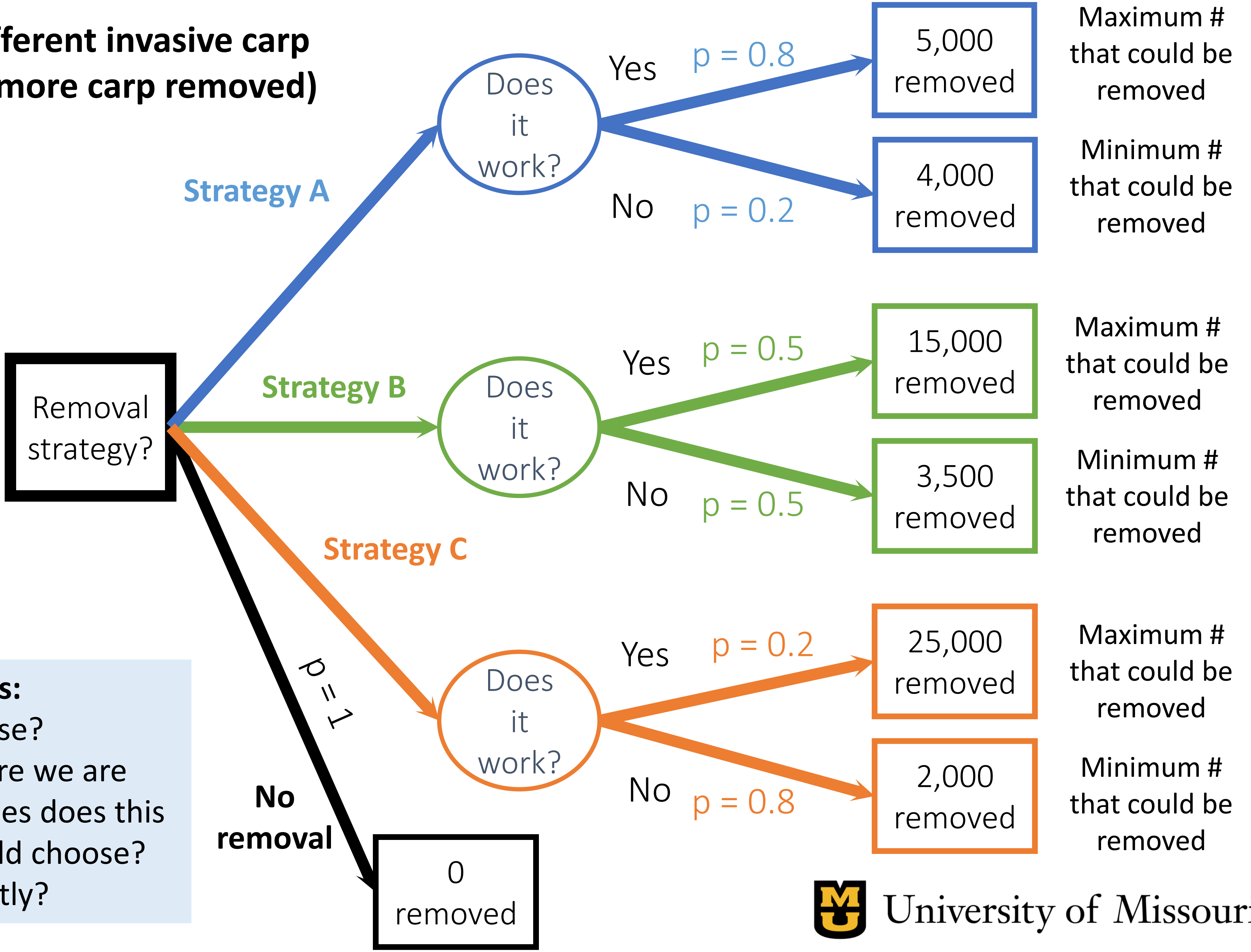
Skills Check: Risk attitudes

You are choosing between different invasive carp removal strategies (you want more carp removed)

Across removal strategies find each EV & identify:

1) The strategy for a risk-neutral decision maker (the highest EV)
2) The strategy for a risk-averse decision maker (best mini-max)
3) Identify the strategy for a risk-seeker



& Answer the questions:

- Which strategy would you choose?
- What if this was a decision where we are reintroducing endangered species does this change which strategy you would choose? Would you address risk differently?

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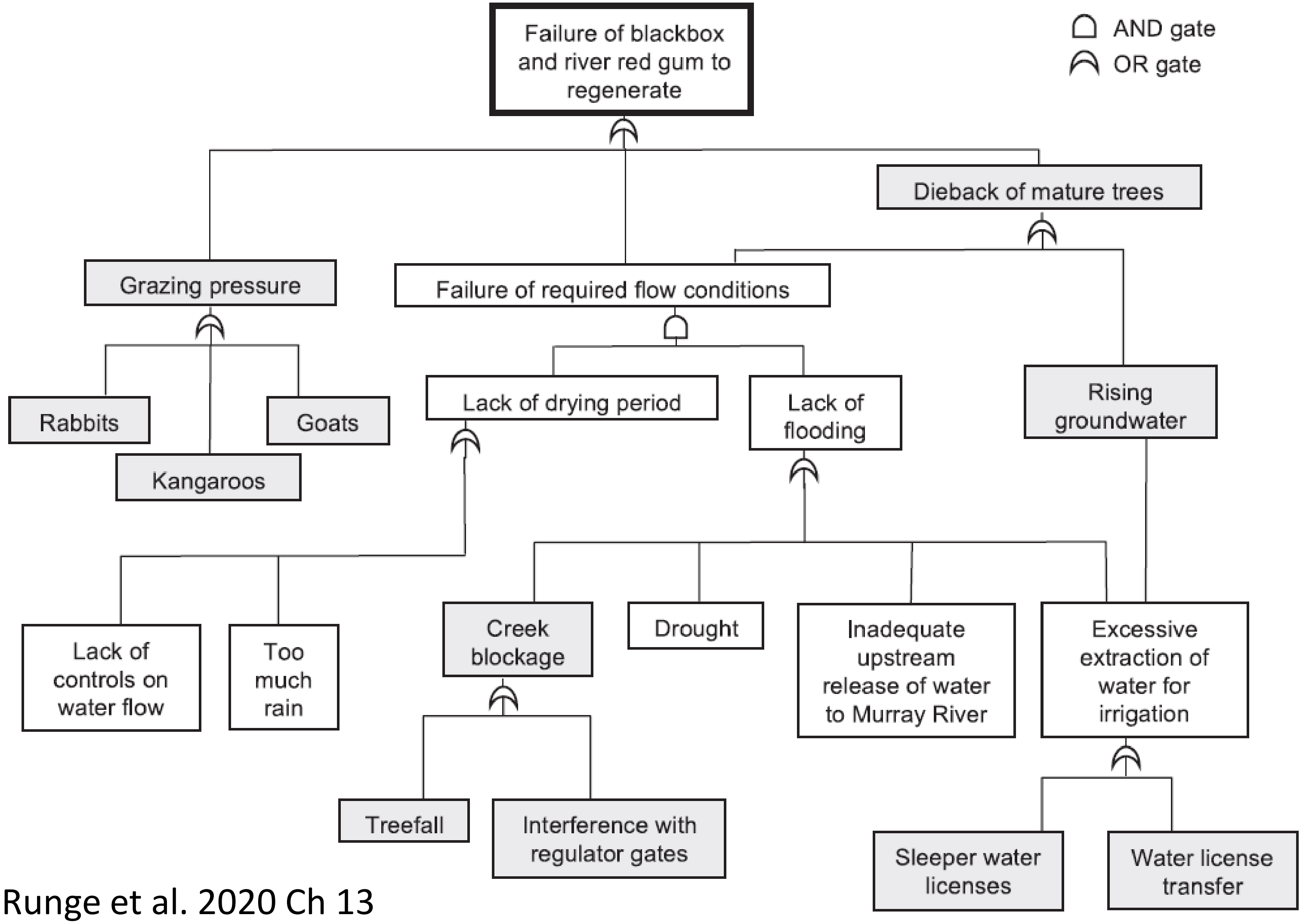
Tools to handle identify and deal with uncertainty:

- Decision trees
- Fault trees

Fault trees

- Infrequently used



Runge et al. 2020 Ch 13

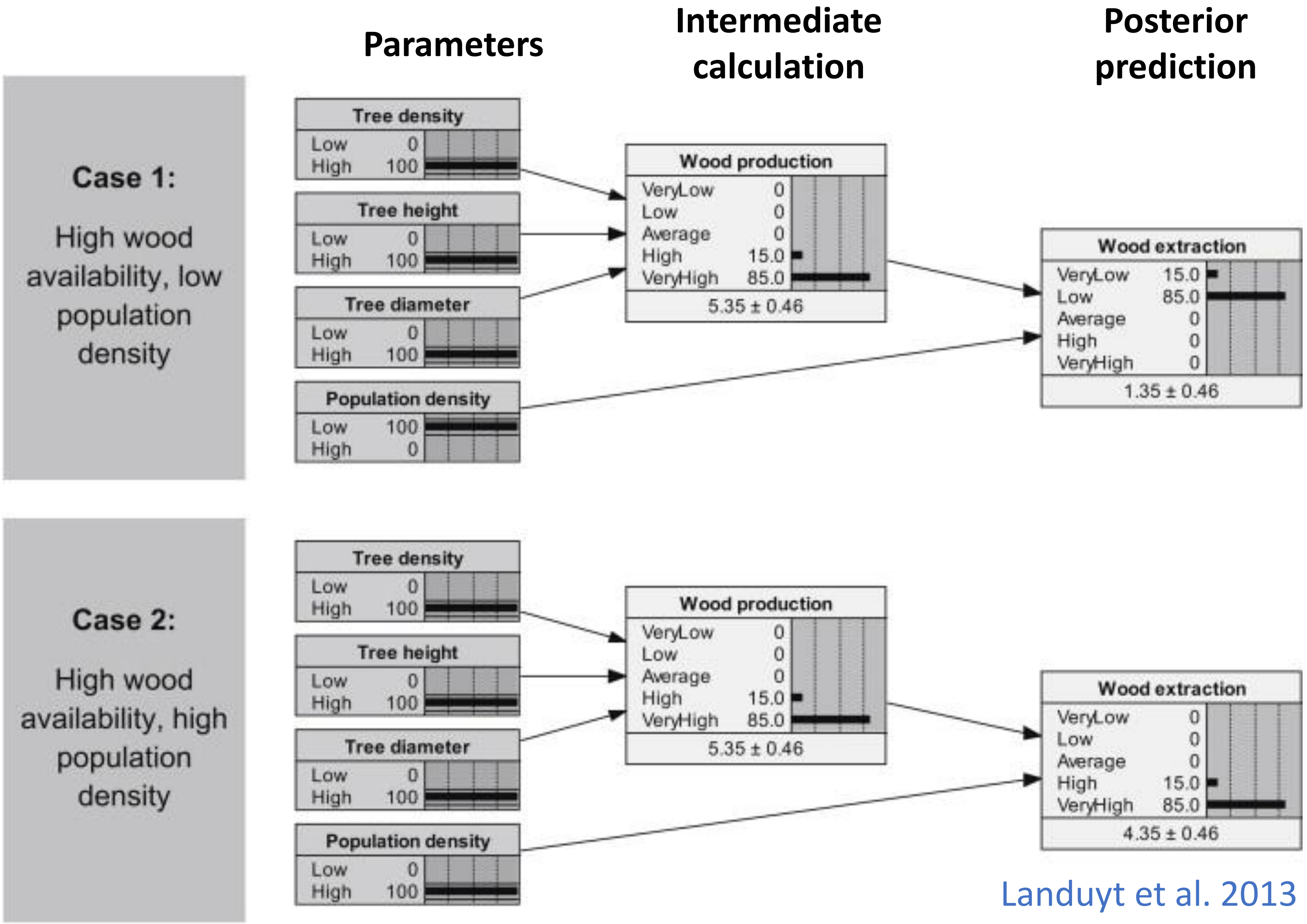
Figure 13.1. A fault tree illustrating various events that can lead to failure of black box and river red gum trees to regenerate. Each box represents a separate type of event, and the hierarchical structure shows how those events combine to lead to the top-level failure. "OR gates," such as that immediately below the top-level failure box, indicate that any 1 of the events below is sufficient to lead to the failure. "AND gates" indicate that all of the lower-level events must occur for the failure to occur. The shaded boxes were added in a second iteration, demonstrating the value of prototyping. *Example from Hattah-Kulkyne National Park, Victoria, Australia, Carey et al. 2005.*

Tools to handle identify and deal with uncertainty:

- Decision trees
- Fault trees
- Bayesian belief nets

Bayesian Belief Network (BBN) models

- Model that incorporates **Bayesian inference** to estimate uncertainty in its predictions
  - Incorporates data, prior distributions, likelihood functions



Landuyt et al. 2013

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Developed by Brielle Thompson, see Landuyt et al. 2013

Tools to handle identify and deal with uncertainty:

- Decision trees
- Fault trees
- Bayesian belief nets
- Integrated population models
  - Integrate data streams to better estimate parameter values
- Expert judgement methods
- Expected value
- Expected utility analysis (utilities elicited via gambles)
- Maxi-min criterion
- Robust satisficing
- Last week (Value of information, adaptive management, sensitivity analysis)

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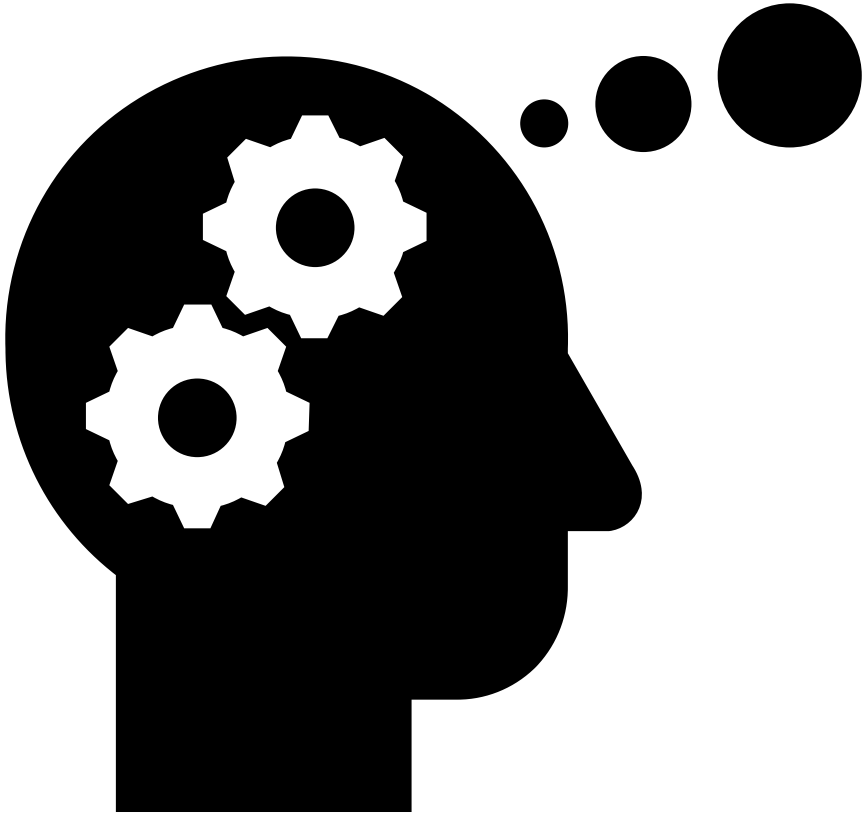
Risk summary

- Decisions in the face of uncertainty
  - Need to consider decision maker’s attitude toward risk
  - This amounts to valuing outcomes in a way that is not necessarily linear relative to gain or loss
  - A utility function can be used to capture the decision maker’s risk attitude

Discussion

- Why should risk tolerance be understood?
- In what ways might a risk-averse decision maker approach a conservation problem differently than a risk-seeking one?



Next week:

final class period
2-4pm ABNR 210

Final presentations!

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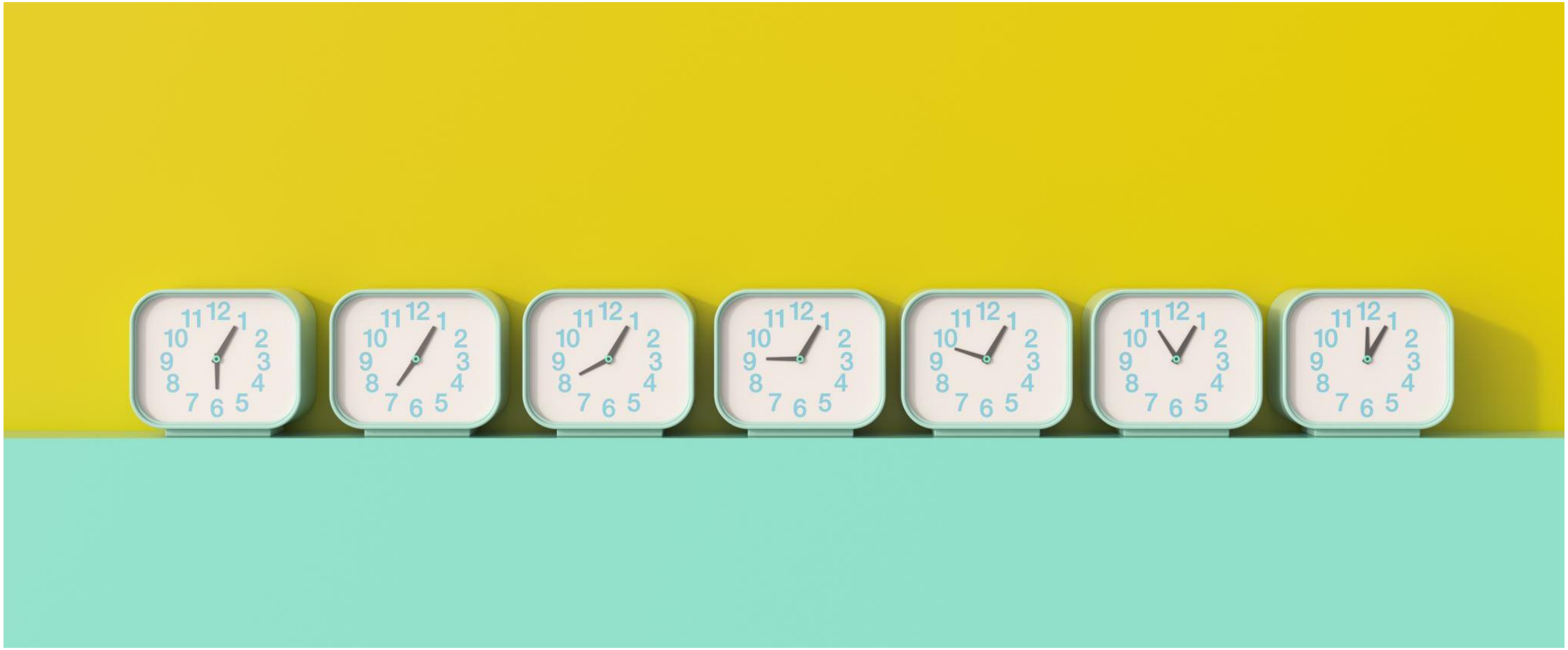
Extra time activities:



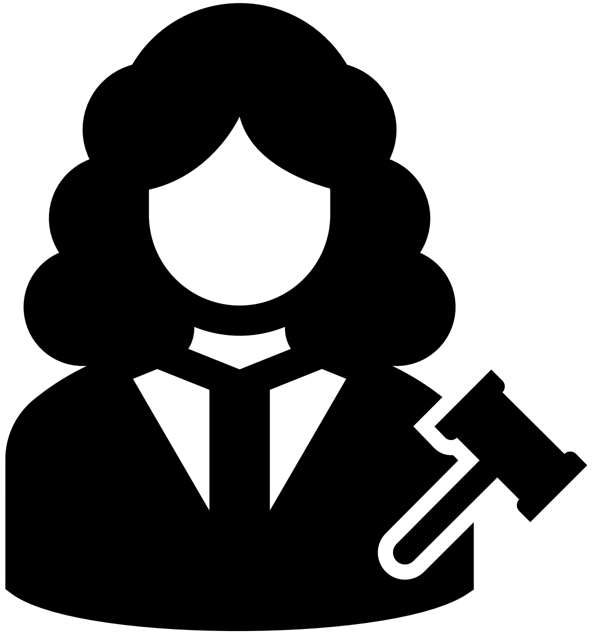
Activity: Risk attitude debate

In the skills check exercise on invasive carp removal strategy B was the best for a risk neutral decision maker, strategy A was the best for a risk-averse decision maker, and strategy C was the best for a risk-seeker.

- Let’s have a risk attitude debate!
  - Group 1 decision maker: Risk-neutral
  - Group 2 decision maker: Risk-averse
  - Group 3 decision maker: Risk-seeking

Instructions:

- You have 5-10 minutes to produce your arguments
- You will have one spokesperson per team for round 1 of arguments
- A separate spokesperson will argue for round 2 -rebuttals



Reading discussion (Runge et al. 2020 Ch 13)

1. How does risk tolerance influence the choice between management actions with uncertain outcomes?
2. How does expected utility theory help integrate scientific uncertainty with stakeholder values? What challenges might arise when eliciting utility functions from decision makers?
3. How might cognitive biases affect how decision makers perceive and respond to risk in conservation settings? What strategies can help mitigate these biases?
4. In what ways can structured decision making tools help clarify value-based disagreements among stakeholders in conservation planning?