University of Missouri

Tradeoffs

Module 6:

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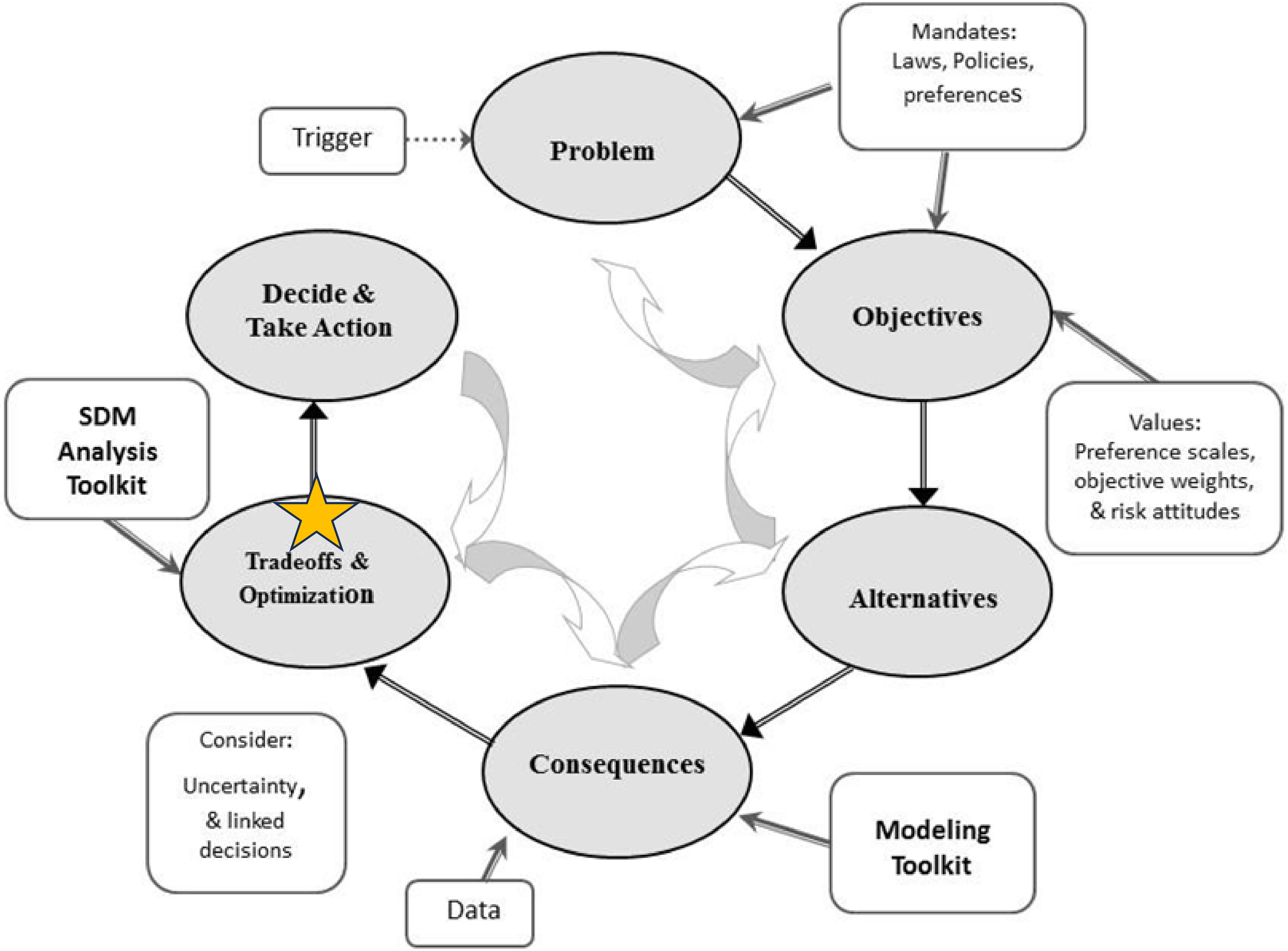
Workshop: An overview of Structured Decision Making for natural resources,
Midwest Fish and Wildlife Conference 2025, St. Louis, MO

Modified from: Fundamentals of Structured Decision Making TWS Conference Workshop 2023 & an Overview of Structured Decision-Making Washington Department of Fish and Wildlife 2022-2023



Source: Jean Fitts Cochrane

Tradeoffs

"How much you would give up on one objective in order to achieve gains on another objective"

- Gregory et al. 2012

Role of analytical methods in tradeoff analysis

- Identify “best” (optimal) solution
  - Ties together alternatives, objectives, and predicted consequences
  - How do you integrate all the components?
- Easiest with a single objective
- Easiest without uncertainty
- Solution method depends on the structure of the problem

Analytical approaches

	Approach
Single Objective	• Deterministic optimization
Multiple Objectives	• Multiple Attribute Utility • Simplification • SMART • Pareto frontier analysis
	Negotiate among most efficient alternatives

Increased complexity

Single objective approach:

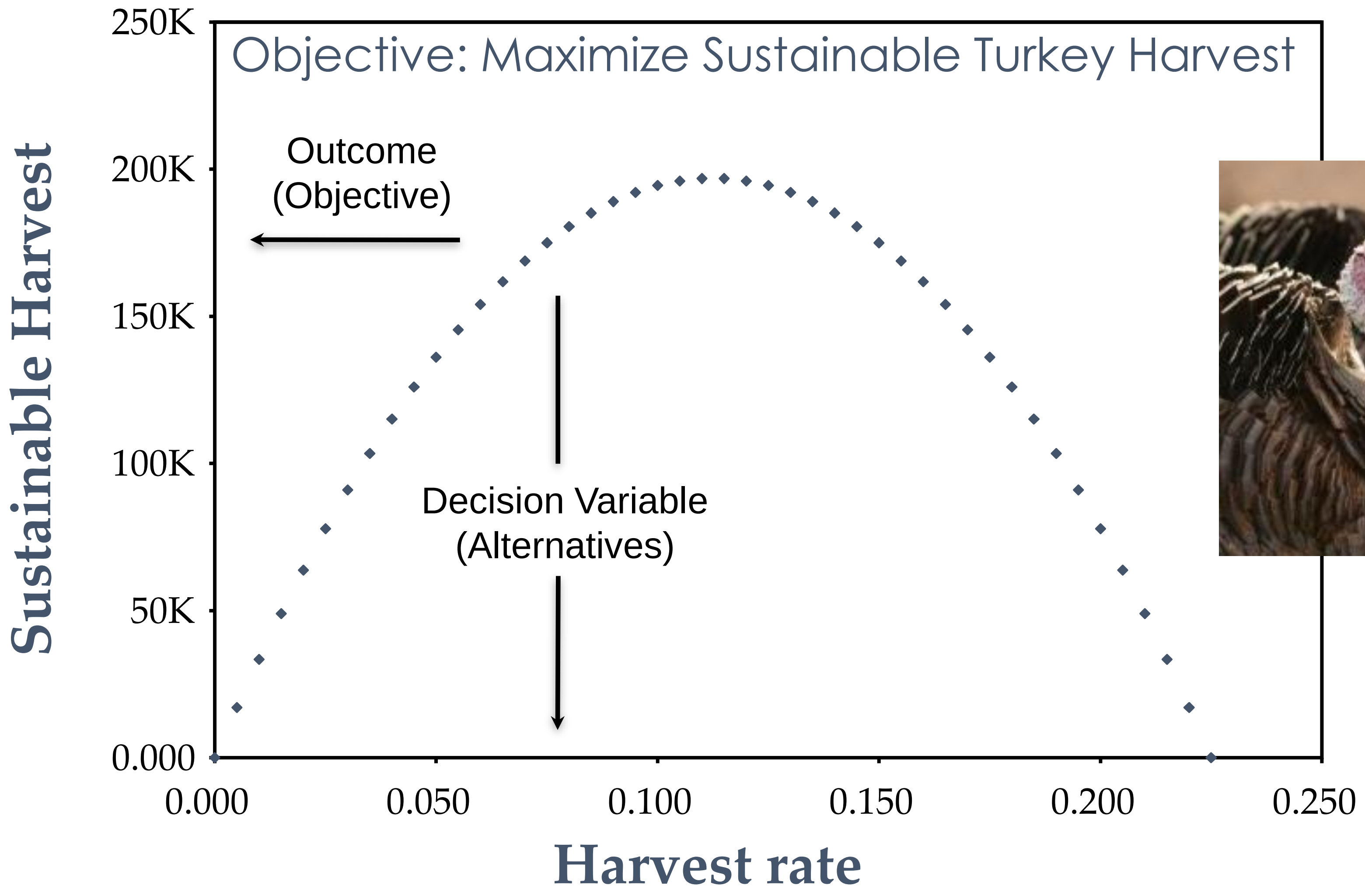
- Used when we have a single continuous decision variable (i.e., alternatives)
  - e.g., harvest rate, amount of herbicide to apply, size of biocontrol release, etc.

- Predict outcomes (i.e., objective) are a function of the decision variable

- Optimization solution methods:
  - Graphical
  - Closed-formed solutions (calculus/differentiation)
  - Numerical solutions (mathematical search methods)
  - Constrained optimization (mathematical solution)

Single objective approach:

- Graphical optimization:



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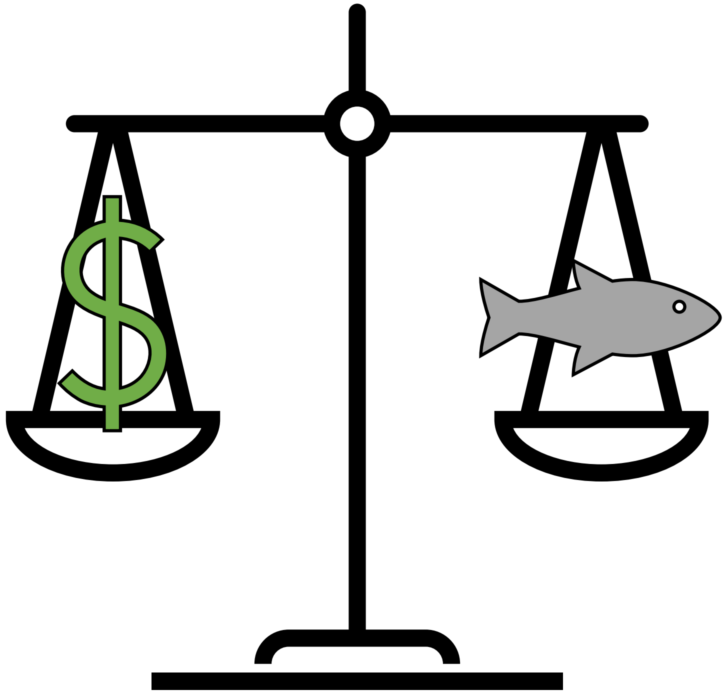
Single objective approach:

Question: Can you think of an example of a single objective problem?

- Not very common in natural resource management.
- Single objectives are easier to optimize, so we may want to reduce multiple objective problems to make them easier to solve.

Multiple objective tools

- Nearly all natural resource management problems are multiple-objective problems



Multiple objective tools

A. Simplify the problem as much as possible
   1. Remove dominated alternatives
   2. Remove irrelevant objectives
   3. Make even swaps

B. Reduce to a single objective if possible

C. Negotiate a solution from a set of best compromises

D. Evaluate trade-offs explicitly

A. Simplify the problem

1. Remove dominated alternatives:

- i.e., another alternative performs the same or better on all objectives

A. Simplify the problem (EXAMPLE)

1. Remove dominated alternatives (another alternative performs the same or better on all objectives)

Objectives	Direction	Alternatives			
		Status quo	Minor repair	Major repair	Re-build
Cost ($M)	Min				
Environmental Benefit (0-10)	Max				
Disturbance (0-10)	Min				
Silt runoff (k ft^3)	Min				
Water Retention (MG)	Max				

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1. Remove dominated alternatives (another alternative performs the same or better on all objectives)

Objectives	Direction	Alternatives			
		Status quo	Minor repair	Major repair	Re-build
Cost ($M)	Min	0	2	12	20
Environmental Benefit (0-10)	Max	1	3	10	10
Disturbance (0-10)	Min	0	1	7	10
Silt runoff (k ft^3)	Min	5	1	3	3
Water Retention (MG)	Max	41	41	41	39

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Dominated Alternative

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A. Simplify the problem

1. Remove dominated alternatives:
    - i.e., another alternative performs the same or better on all objectives

2. Remove irrelevant objectives:
- i.e., performance measures of that objective does not vary over alternatives
- This isn’t to say the objective isn’t important to you, just that it doesn’t help discern among the alternatives <u>currently considered.</u>

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2. Remove irrelevant objective

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Dominated Alternative

Irrelevant Objective

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- **Simplified problem:**

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3. Make even swaps:
   - If two objectives are in the same unit, then combine outcomes

A. Simplify the problem (EXAMPLE)

3. Even swaps

Convert silt runoff to cost @ $0.5M / k ft^3

Objectives	Direction	Alternatives		
		Status quo	Minor repair	Major repair
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Cost ($M)	Min	0	2	12
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Disturbance (0-10)	Min	0	1	7
Silt runoff (k ft^3)	Min	~~5~~ 2.5 M	~~1~~ 0.5 M	~~3~~ 1.5 M

A. Simplify the problem (EXAMPLE)

3. Even swaps

Convert silt runoff to cost @ $0.5M / k ft^3

Objectives	Direction	Alternatives		
		Status quo	Minor repair	Major repair
Cost ($M)	Min	0 + 2.5	2 + 0.5	12 + 1.5
Environmental Benefit (0-10)	Max	1	3	10
Disturbance (0-10)	Min	0	1	7
Silt runoff (k ft^3)	[redacted]	[redacted]	[redacted]	[redacted]

B. Reduce to a single objective

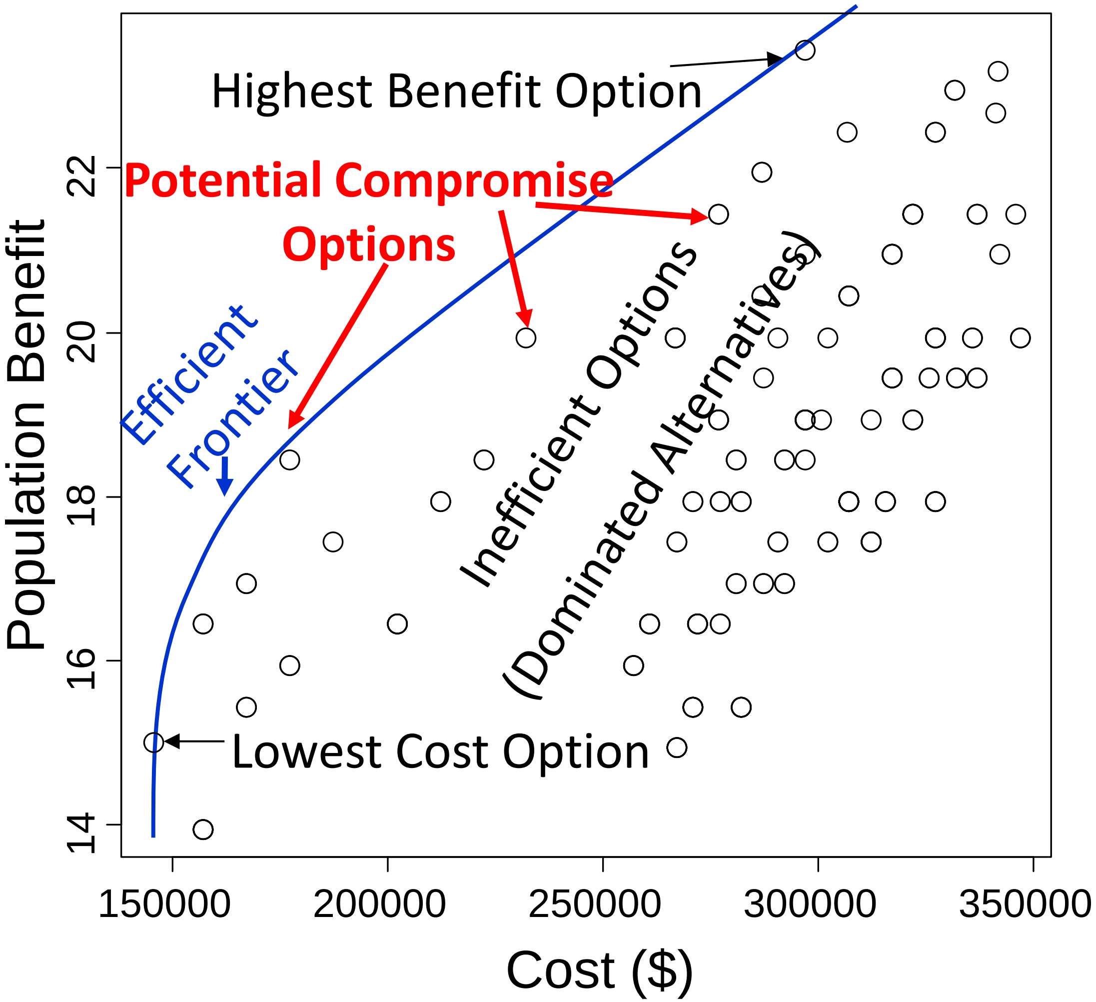
- Tip: Convert all objectives but one to constraints
  - Example: don’t spend more than $2.5M
  - Keep disturbance at or below 3
  - Then take the maximum environmental benefit

Objectives	Direction	Alternatives		
		Status quo	Minor repair	Major repair
Cost ($M)	Min	2.5	2.5	13.5
Environmental Benefit (0-10)	Max	1	3	10
Disturbance (0-10)	Min	0	1	7

C. Negotiate a solution from a set of best compromises

- With > two objectives we can do **pareto frontier analysis**

Example:
Cost
vs
Population
Benefit



◯ = outcome of each alternative

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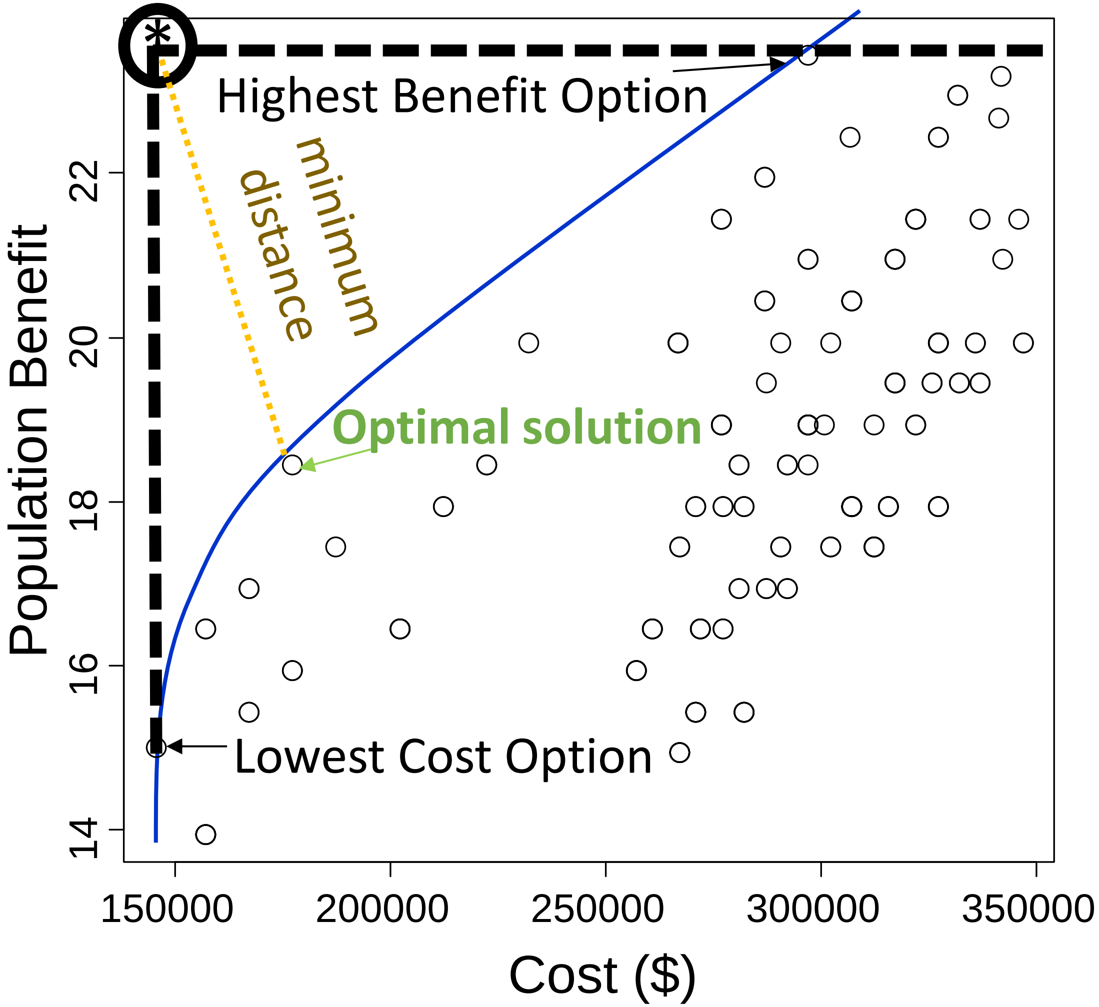


◯ = outcome of each alternative

If cost and population benefit are deemed equal, we can find the **optimal solution** as the minimum distance between the ideal point (*)

Example: Consequence table + tradeoffs

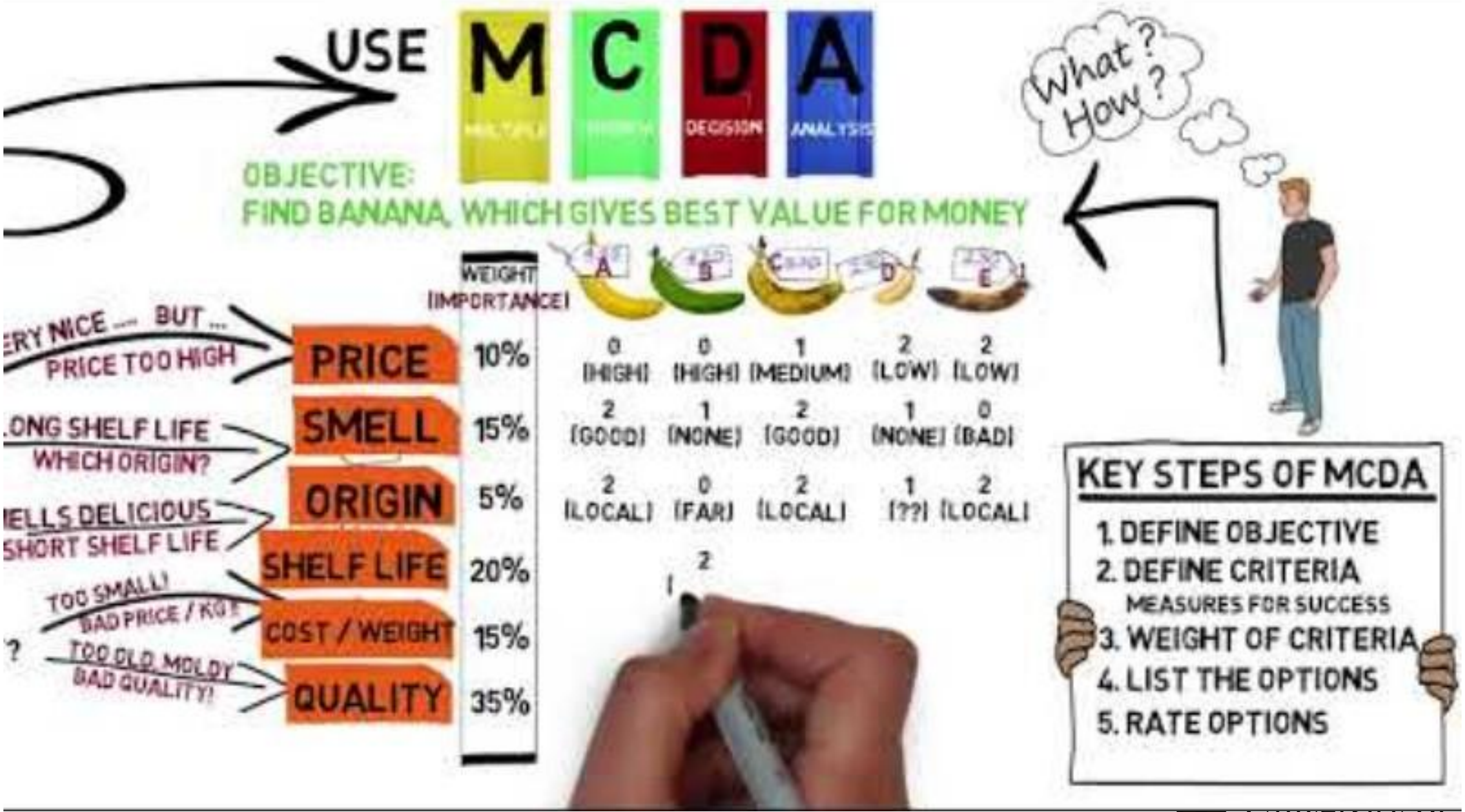
Thompson, Olden, & Converse 2024 *NeoBiota*

Alternative management strategy, no. segments of removal effort	Objective (expected value)			Dominated by X Alternative
	Suppression (in millions)	Containment (%)	Prevention (in millions)	
No removals, 0	21.13 M	90.3%	1.15 M	None
Abundance, 1	**20.52 M**	90.2%	1.15 M	None
Growth, 1	20.83 M	**89.7%**	1.15 M	None
Edges, 1	20.68 M	90.0%	0.83 M	None
Downstream, 1	20.81 M	90.1%	**0.48 M**	None
Random, 1	20.61 M	90.0%	1.10 M	None
Abundance, 4	**18.82 M**	89.6%	1.14 M	None
Growth, 4	20.05 M	87.2%	1.01 M	Downstream, 4
Edges, 4	19.24 M	88.1%	0.48 M	None
Downstream, 4	19.37 M	**86.2%**	**0.18 M**	None
Random, 4	19.00 M	88.6%	0.96 M	None
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
Abundance, 16	**11.81 M**	74.1%	0.67 M	None
Growth, 16	14.25 M	72.9%	0.22 M	Edges, 16
Edges, 16	14.24 M	**71.4%**	0.22 M	None
Downstream, 16	13.17 M	73.7%	**0.15 M**	None
Random, 16	12.78 M	78.3%	0.56 M	None

D. Evaluate trade-offs explicitly

- Multicriteria decision analysis:
  - Offers tools to evaluate multiple objective problems
- A variety of tools exist (beyond the scope of this workshop)
  - Outranking methods
  - Analytic Hierarchy Process
  - Multi-attribute value/utility theory
  - SMART (simple multi-attribute rating technique)

3-minute intro to MCDA



Case study: (Runge et al. 2011)

- See attachment of case study description (CaseStudyDescription.pdf)

Exercise: Evaluate tradeoffs

Hint: Are there any irrelevant objectives, dominated outcomes, even swaps?

Objective [measurable attribute] {Direction}

	Alternative	Respect Life	HBC Recovery	Wilderness Disturbance	Cost
		[0-10 scale]	[P(N>6000)]	[User-days]	[M$/5-yr]
		{Max}	{Max}	{Min}	{Min}
A	**No action**	**6**	**0.2**	**0**	**0**
B	**Alternative B**	**7**	**0.3**	**30**	**2.5**
C	**Alternative C**	**6**	**0.3**	**40**	**3**
D	**Alternative D**	**9.5**	**0.3**	**50**	**4.5**
E	**Alternative E**	**9**	**0.25**	**60**	**2**

The consequence table was inspired by Runge et al. 2011
but the values in the table were altered for simplicity