Expected Value of Information

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Expected Value of Information

- A measure of how much the outcome of management would improve if uncertainty could be fully resolved
- A classic technique for decision analysis
  - Very much underused in adaptive management settings
- Calculation requires
  - Articulation of alternative hypotheses
  - Prediction of the outcome of each possible action under each hypothesis
  - *A priori* weights on the alternative hypotheses

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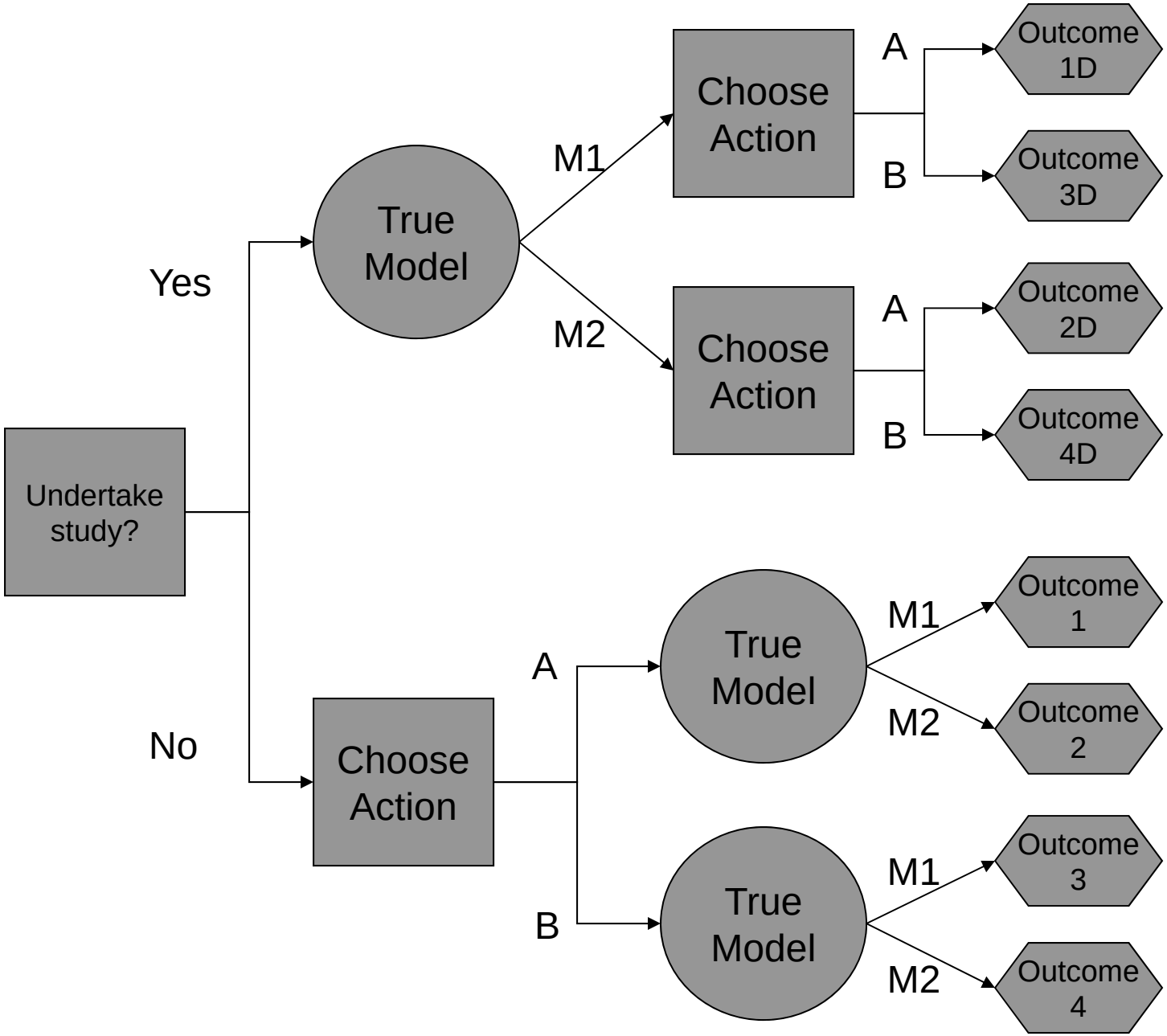

Undertake study?
Yes
No
True Model
M1
M2
Choose Action
Choose Action
A
B
A
B
Outcome 1D
Outcome 3D
Outcome 2D
Outcome 4D
Choose Action
A
B
True Model
True Model
M1
M2
M1
M2
Outcome 1
Outcome 2
Outcome 3
Outcome 4

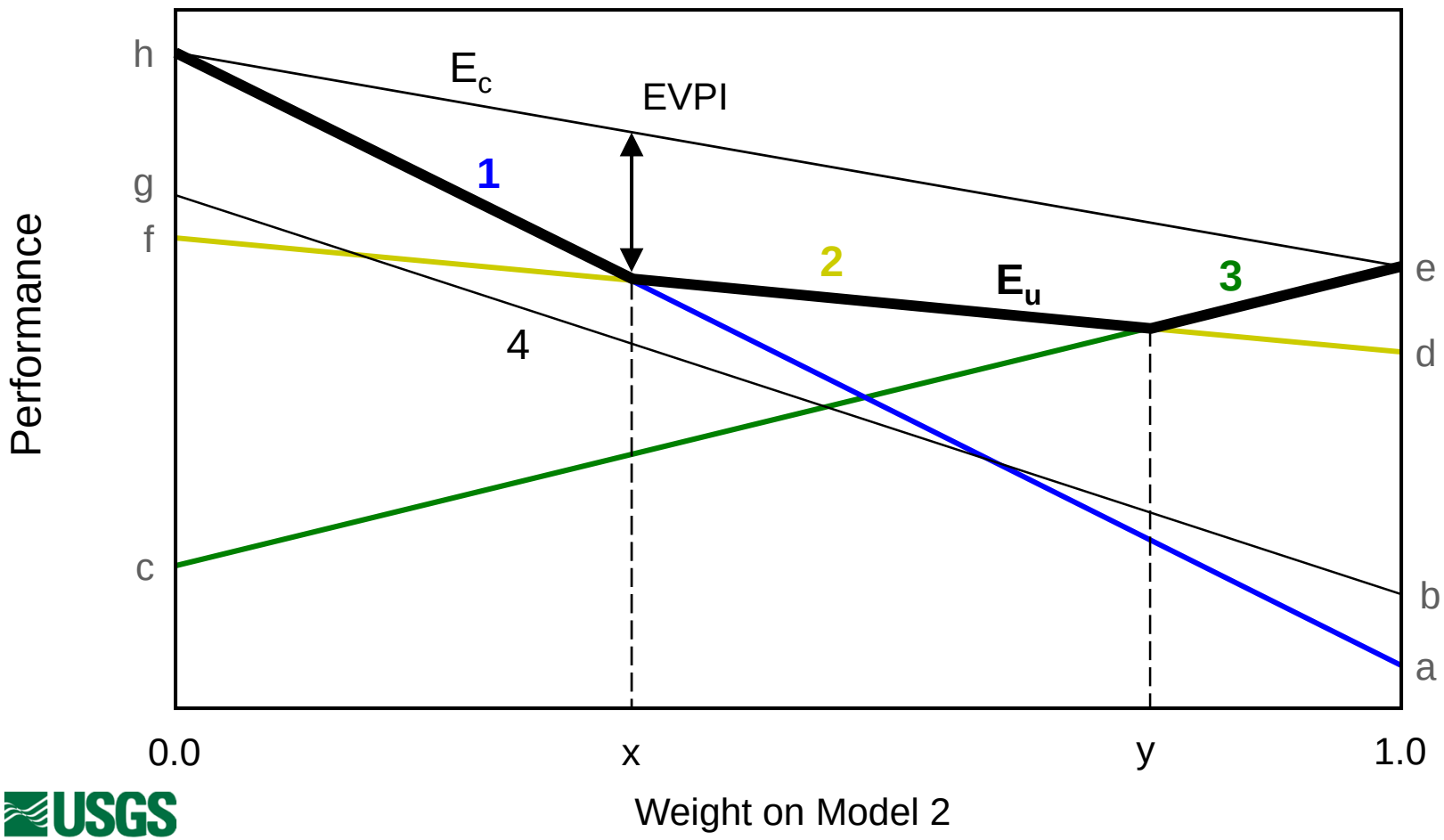
Expected Value of Perfect Information

- Notation
  - A set of actions indexed by a
  - A set of models indexed by s (and a distribution on them)
  - A reward function given by utility U
- EVPI

$$EVPI = E_s\left[\max_a U(a,s)\right] - \max_a E_s\left[U(a,s)\right]$$
$$= E_s\left[\max_a U(a,s)\right] - \max_a \bar{U}(a)$$

- Calculates the difference between the expected return if you resolve uncertainty before you make your decision and the expected return if you make your decision before (or without) resolving uncertainty

A Graphical Picture of EVPI



Partial EVPI

- Notation
  - Now subdivide the uncertainty into two pieces, s_i and its complement, s_i^c
- Expected value of perfect X information (partial EVPI)

$$EVPXI\left(s_i\right) = E_{s_i}\left[\max_a E_{s_i^c}\left[U\left(a, s_i, s_i^c\right)\right]\right] - \max_a E_{s_i, s_i^c}\left[U\left(a, s_i, s_i^c\right)\right]$$

- The expected improvement in performance for resolving the uncertainty associated with the subset s_i

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Expected Value of Sample Information

- Notation
  - Some sample information, x, is gathered

- Expected value of sample information

$$EVSI = E_x\left[\max_a E_{s|x}\left[U\left(a,s\right)\right]\right] - \max_a E_s\left[U\left(a,s\right)\right]$$

- Expected improvement in performance due to change in knowledge from having taken sample *x*
  - Bayesian preposterior analysis
  - Posterior is $s|x$
  - But have to take expectation over x, under the prior s

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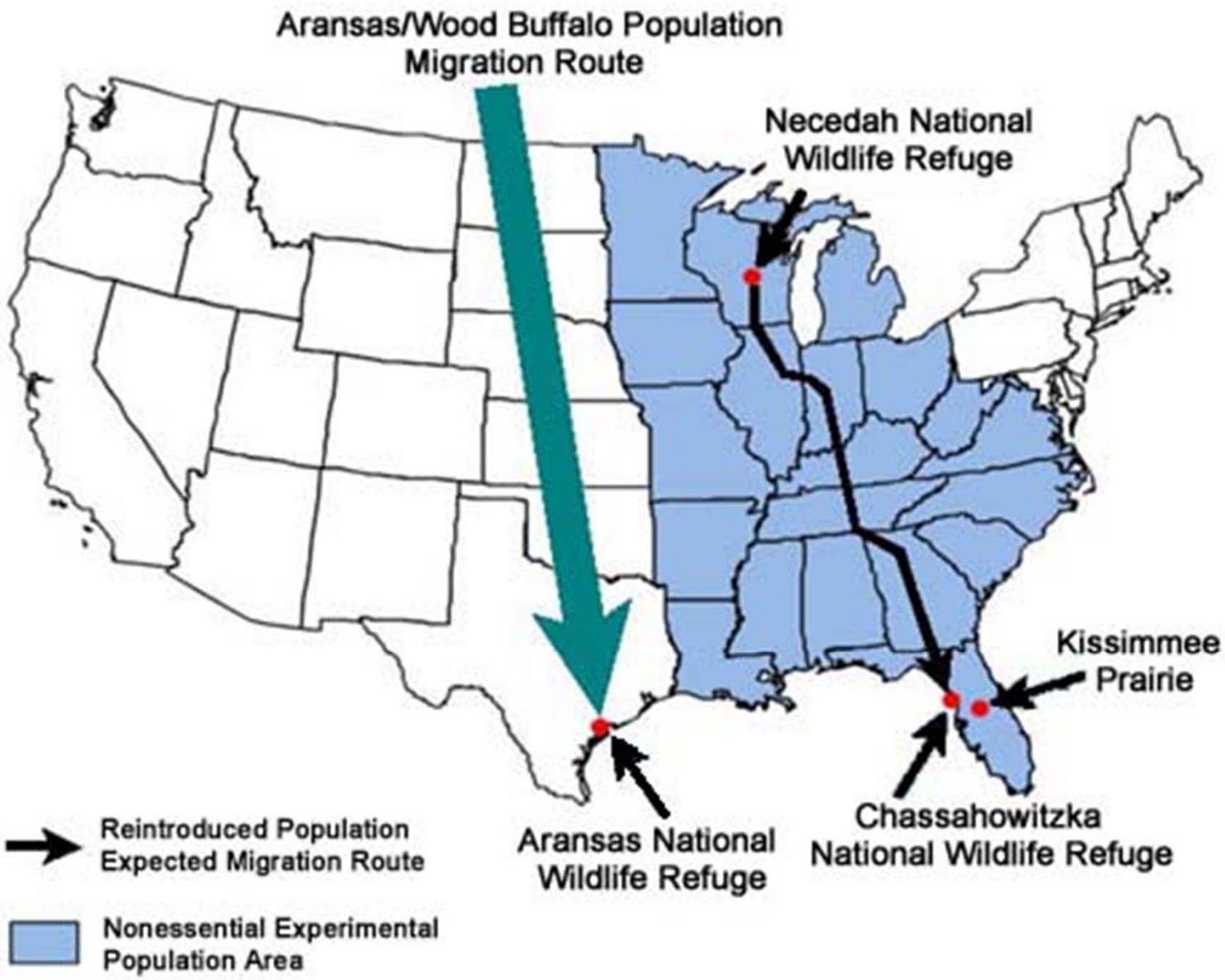
Aransas/Wood Buffalo Population
Migration Route
Necedah National
Wildlife Refuge
Kissimmee
Prairie
Chassahowitzka
National Wildlife Refuge
Aransas National
Wildlife Refuge
Reintroduced Population
Expected Migration Route
Nonessential Experimental
Population Area

Eastern Migratory Population

Year	Nests	Chicks
2001	0	0
2002	0	0
2003	0	0
2004	0	0
2005	2	0
2006	6	2 (1 fledged)
2007	5	0
2008	11	0
2009	17	2 (0 fledged)

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Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Too Young									
Black flies									
Social									
Nutrient: NNWR									
Nutrient: winter									
Nutrient: both									
Egg Salvage									
Disturbance									
Expected Value									

Predicted Reproductive Success

Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Too Young									
Black flies		0.07	0.20	0.13	0.12	0.12	0.20	0.10	
Social									
Nutrient: NNWR									
Nutrient: winter									
Nutrient: both									
Egg Salvage									
Disturbance									
Expected Value									

Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Too Young		0.25	0.22	0.24	0.24	0.26	0.22	0.18	
Black flies		0.07	0.20	0.13	0.12	0.12	0.20	0.10	
Social		0.07	0.10	0.11	0.14	0.14	0.11	0.19	
Nutrient: NNWR		0.07	0.09	0.14	0.29	0.29	0.10	0.12	
Nutrient: winter		0.07	0.09	0.13	0.14	0.16	0.10	0.12	
Nutrient: both		0.07	0.09	0.14	0.24	0.25	0.12	0.12	
Egg Salvage		0.09	0.23	0.23	0.15	0.13	0.17	0.11	
Disturbance		0.09	0.15	0.25	0.13	0.11	0.11	0.15	
Expected Value									

Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Too Young		0.25	0.22	0.24	0.24	0.26	0.22	0.18	0.26
Black flies		0.07	0.20	0.13	0.12	0.12	0.20	0.10	0.20
Social		0.07	0.10	0.11	0.14	0.14	0.11	0.19	0.19
Nutrient: NNWR		0.07	0.09	0.14	0.29	0.29	0.10	0.12	0.29
Nutrient: winter		0.07	0.09	0.13	0.14	0.16	0.10	0.12	0.16
Nutrient: both		0.07	0.09	0.14	0.24	0.25	0.12	0.12	0.25
Egg Salvage		0.09	0.23	0.23	0.15	0.13	0.17	0.11	0.23
Disturbance		0.09	0.15	0.25	0.13	0.11	0.11	0.15	0.25
Expected Value									

Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Too Young	9.4%	0.25	0.22	0.24	0.24	0.26	0.22	0.18	0.26
Black flies	29.1%	0.07	0.20	0.13	0.12	0.12	0.20	0.10	0.20
Social	11.9%	0.07	0.10	0.11	0.14	0.14	0.11	0.19	0.19
Nutrient: NNWR	22.8%	0.07	0.09	0.14	0.29	0.29	0.10	0.12	0.29
Nutrient: winter	5.9%	0.07	0.09	0.13	0.14	0.16	0.10	0.12	0.16
Nutrient: both	6.6%	0.07	0.09	0.14	0.24	0.25	0.12	0.12	0.25
Egg Salvage	4.4%	0.09	0.23	0.23	0.15	0.13	0.17	0.11	0.23
Disturbance	10.0%	0.09	0.15	0.25	0.13	0.11	0.11	0.15	0.25
Expected Value									

Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Too Young	9.4%	0.25	0.22	0.24	0.24	0.26	0.22	0.18	0.26
Black flies	29.1%	0.07	0.20	0.13	0.12	0.12	0.20	0.10	0.20
Social	11.9%	0.07	0.10	0.11	0.14	0.14	0.11	0.19	0.19
Nutrient: NNWR	22.8%	0.07	0.09	0.14	0.29	0.29	0.10	0.12	0.29
Nutrient: winter	5.9%	0.07	0.09	0.13	0.14	0.16	0.10	0.12	0.16
Nutrient: both	6.6%	0.07	0.09	0.14	0.24	0.25	0.12	0.12	0.25
Egg Salvage	4.4%	0.09	0.23	0.23	0.15	0.13	0.17	0.11	0.23
Disturbance	10.0%	0.09	0.15	0.25	0.13	0.11	0.11	0.15	0.25
Expected Value		**0.091**	**0.147**	**0.155**	**0.185**	**0.183**	**0.148**	**0.129**	**0.232**

Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Too Young	9.4%	0.25	0.22	0.24	0.24	0.26	0.22	0.18	0.26
Black flies	29.1%	0.07	0.20	0.13	0.12	0.12	0.20	0.10	0.20
Social	11.9%	0.07	0.10	0.11	0.14	0.14	0.11	0.19	0.19
Nutrient: NNWR	22.8%	0.07	0.09	0.14	0.29	0.29	0.10	0.12	0.29
Nutrient: winter	5.9%	0.07	0.09	0.13	0.14	0.16	0.10	0.12	0.16
Nutrient: both	6.6%	0.07	0.09	0.14	0.24	[illegible]	[illegible]	[illegible]	25
Egg Salvage	4.4%	0.09	0.23	0.23	0.15	0.13	0.17	0.11	0.23
Disturbance	10.0%	0.09	0.15	0.25	0.13	0.11	0.11	0.15	0.25
Expected Value		**0.091**	**0.147**	**0.155**	**0.185**	**0.183**	**0.148**	**0.129**	**0.232**

Expected Value of Perfect Information: 0.047

Multiple Objectives

Objective	EV (uncertainty)	EV (certainty)	EVPI
Number of crane pairs nesting on the refuge	16.8	16.8	0.0%
Reproductive success	0.185	0.232	25.7%
Adult survival	0.934	0.936	0.3%
Condition of departing birds	3.050	3.057	0.2%
Weighted Avg	0.590	0.707	19.9%

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Partial Information

Using the Weighted Average Performance across Objectives

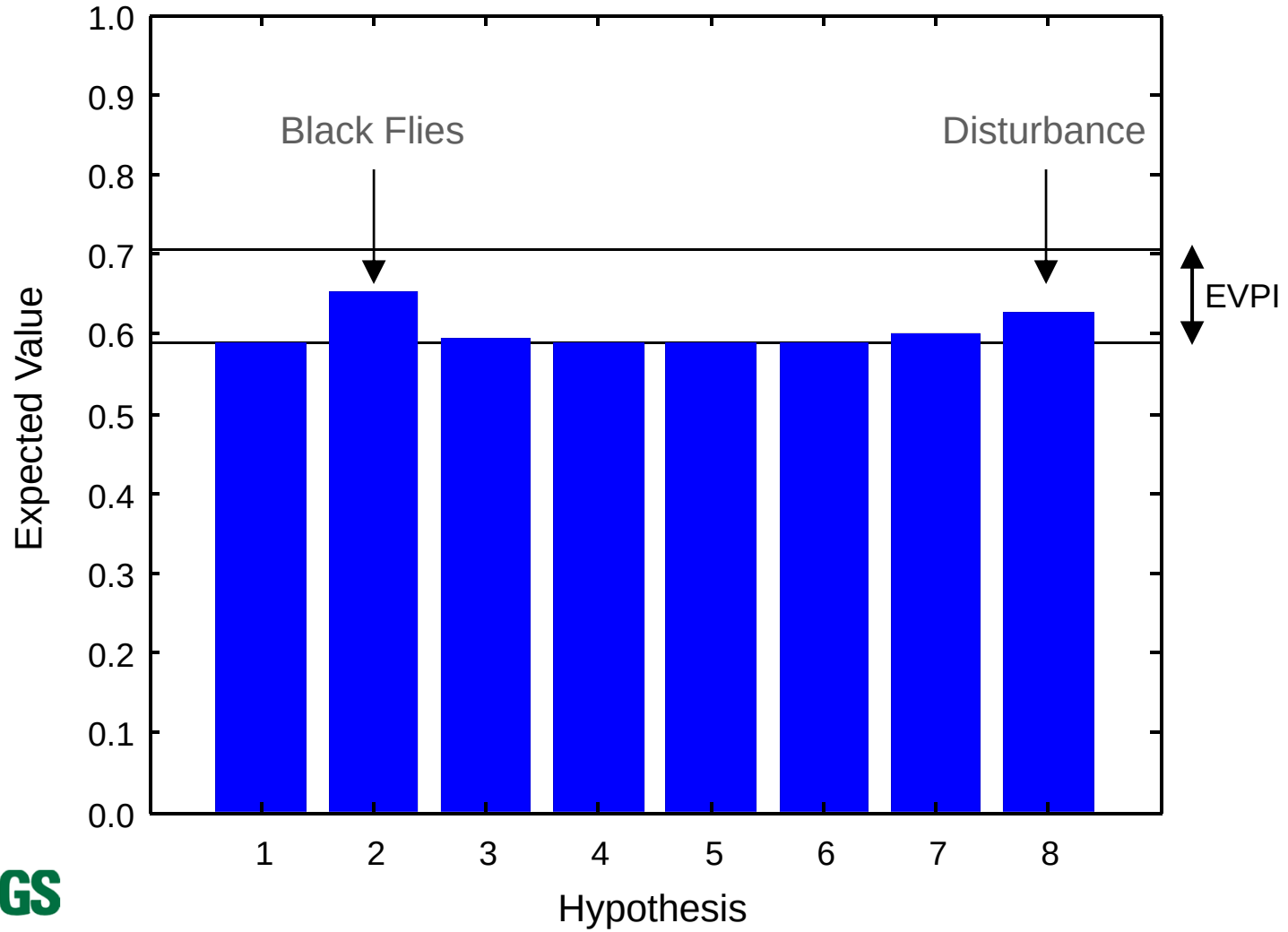
Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Too Young	9.4%	0.59	0.49	0.58	0.73	0.66	0.54	0.40	0.73
Black flies	29.1%	0.02	0.42	0.24	0.37	0.25	0.59	0.14	0.59
Social	11.9%	0.09	0.15	0.22	0.43	0.32	0.22	0.49	0.49
Nutrient: NNWR	22.8%	0.04	0.08	0.25	0.99	0.86	0.13	0.17	0.99
Nutrient: winter	5.9%	0.09	0.12	0.26	0.47	0.40	0.18	0.22	0.47
Nutrient: both	6.6%	0.04	0.08	0.24	0.79	0.70	0.17	0.18	0.79
Egg Salvage	4.4%	0.15	0.62	0.66	0.44	0.29	0.35	0.16	0.66
Disturbance	10.0%	0.12	0.39	0.74	0.36	0.22	0.17	0.26	0.74
Expected Value		**0.106**	**0.284**	**0.343**	**0.590**	**0.475**	**0.331**	**0.231**	**0.707**

Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Black flies	29.1%	0.02	0.42	0.24	0.37	0.25	0.59	0.14	0.59
Too Young	9.4%	0.59	0.49	0.58	0.73	0.66	0.54	0.40	0.73
Social	11.9%	0.09	0.15	0.22	0.43	0.32	0.22	0.49	0.49
Nutrient: NNWR	22.8%	0.04	0.08	0.25	0.99	0.86	0.13	0.17	0.99
Nutrient: winter	5.9%	0.09	0.12	0.26	0.47	0.40	0.18	0.22	0.47
Nutrient: both	6.6%	0.04	0.08	0.24	0.79	0.70	0.17	0.18	0.79
Egg Salvage	4.4%	0.15	0.62	0.66	0.44	0.29	0.35	0.16	0.66
Disturbance	10.0%	0.12	0.39	0.74	0.36	0.22	0.17	0.26	0.74
Expected Value		**0.106**	**0.284**	**0.343**	**0.590**	**0.475**	**0.331**	**0.231**	**0.707**

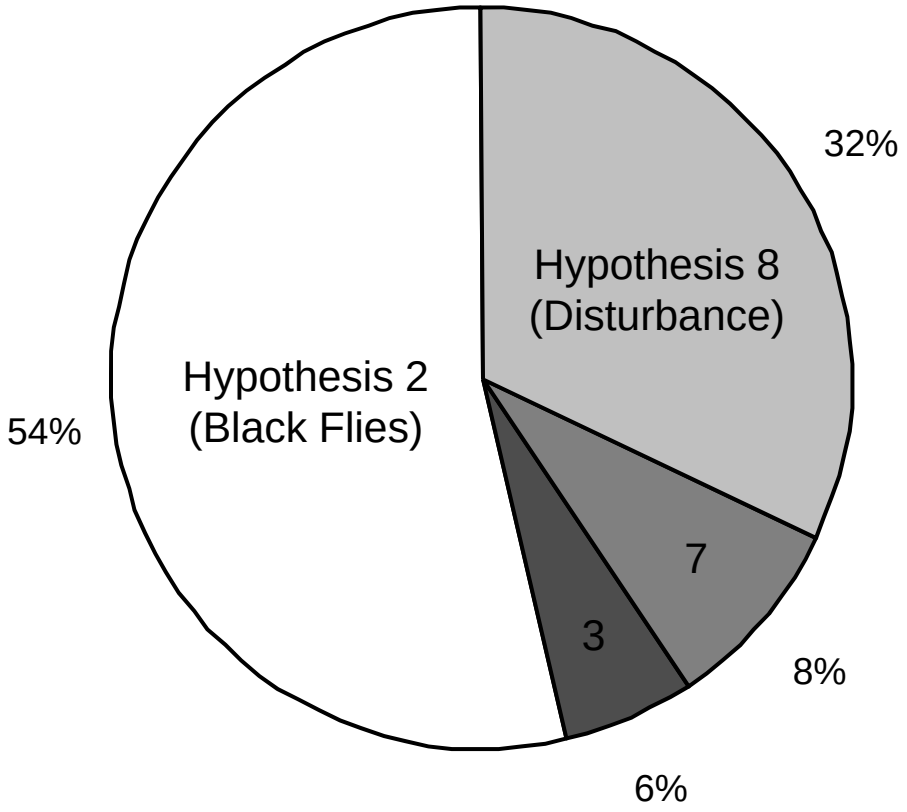
Hypothesis	Weight	Strategy							Best Outcome
		Status quo	Kill flies: Bti & DD	Swap older eggs	Rest-ore mead-ows	April DD & burn	No salv-age	No Distur-bance	
Black flies	29.1%	0.02	0.42	0.24	0.37	0.25	0.59	0.14	0.59
Not Black flies	70.9%	0.14	0.23	0.38	0.68	0.57	0.23	0.27	0.68
Expected Value		**0.106**	**0.284**	**0.343**	**0.590**	**0.475**	**0.331**	**0.231**	**0.653**

Expected Value of Partial Information: 0.063

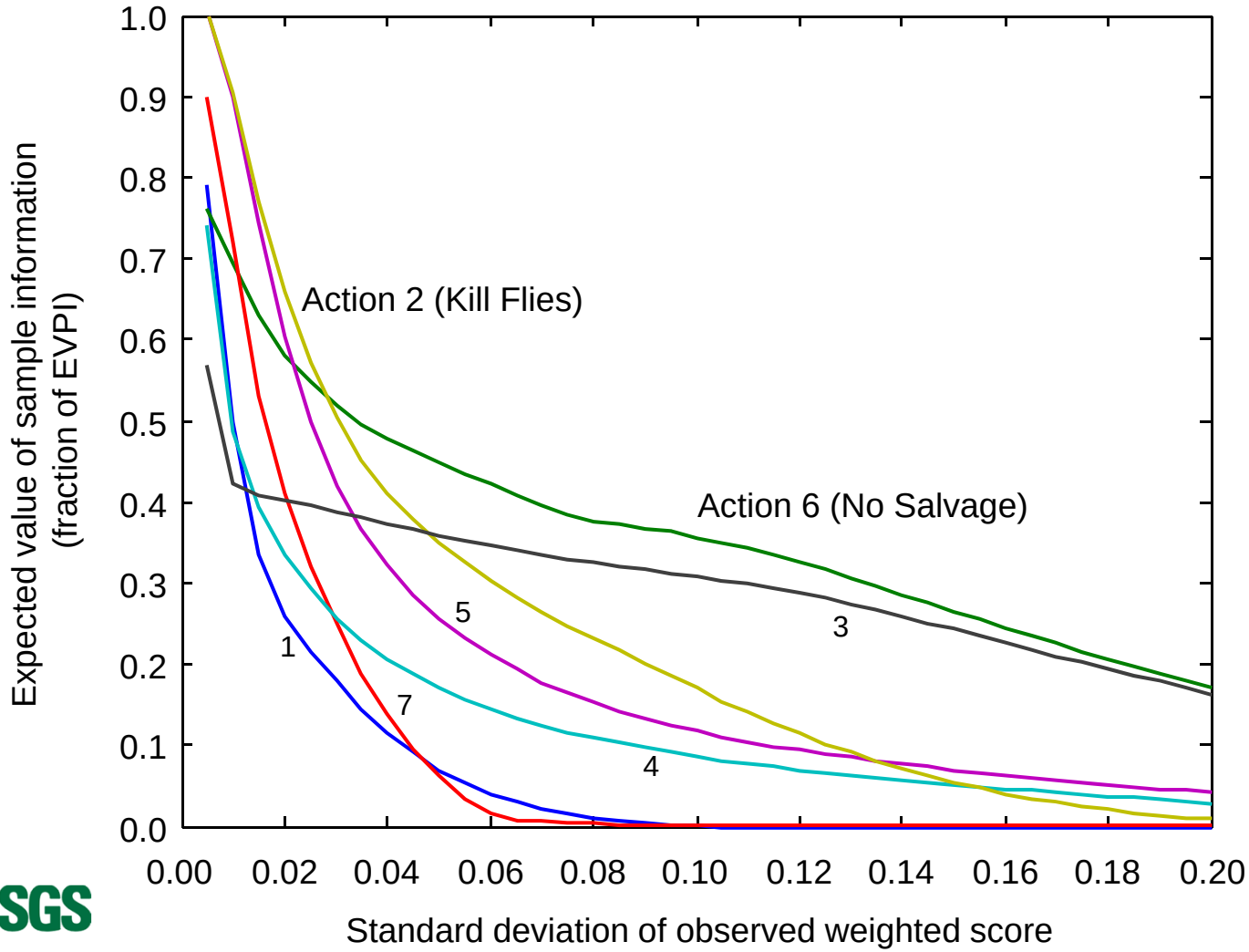
Partial EVPI



Partial EVPI



Expected Value of Sample Information



Conclusions

- The key uncertainty concerns the effect of management on reproductive success
- In the face of uncertainty, best strategy is to restore meadows
- The value of information comes from distinguishing the “black fly” and “disturbance” hypotheses from all the others
- The best strategy in the face of uncertainty is not the most informative strategy
  - Kill flies is informative if the response can be measured precisely
  - No salvage is informative, and quite robust to sampling error

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Adaptive Design

- Monitor: reproductive success
- Test: black fly & disturbance hypotheses; forget the rest
- Valuable probing actions: kill flies, no salvage
- In the face of uncertainty: restore meadows

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Adaptive strategy

- In 2009, set up black fly monitoring program
  - Black fly density on the refuge
  - Black fly density on cranes
  - Synchrony of black fly hatch and nest abandonment
- In 2010, begin experimental black fly control program

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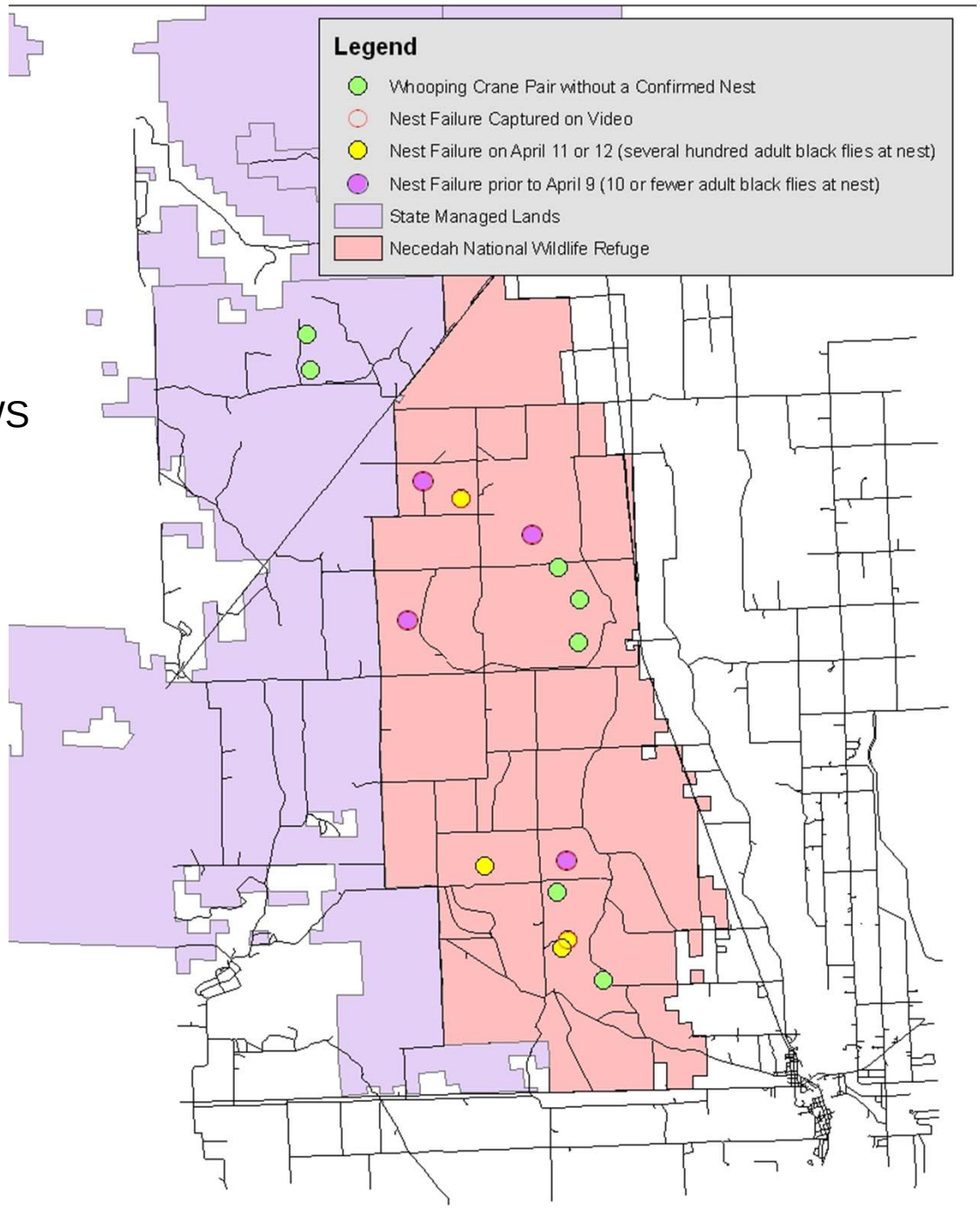
April 15, 2010
Update

Rich King, USFWS



General Messages

- The EVPI calculus, in its various forms, is immensely valuable in identifying
  - The uncertainty to include in an adaptive design
  - The response variables to monitor
  - Actions that might be valuable for learning
- Development of EVPI calculations
  - Does not require extensive data, if expert elicitation can be used

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The Uncertainty that Matters…

- Uncertainty that affects the management action we would take, and results in different performance
  - High expected value of information
- Uncertainty that can be reduced through monitoring (with or without probing management actions)
  - High power to discriminate hypotheses

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Learning as an Objective

- Can learning be a fundamental objective, to be traded off against other objectives?
  - Not in applied work
  - Learning is an alternative, or a component of an alternative, not an objective
  - Unless…it's a strategic objective…

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