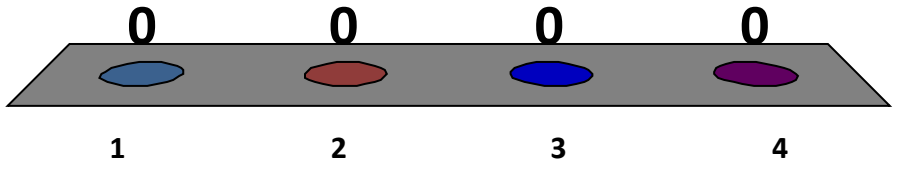
You’re hiking in the woods with a friend, having an intense conversation. Suddenly, you realize it’s an hour till dark and you have no idea where you are. You have no map, and there’s no cell phone reception. What do you do?

What is the most likely response at your office when key data gaps are encountered during a decision-making process?

1. We don't move forward; we don't want to compromise outcomes with inadequate data
2. We find substitute data—it isn't ideal, but it's better than nothing
3. We make acquiring the missing data a higher priority
4. Other



Your pet is sick

9 of 10 vets say it will die without treatment

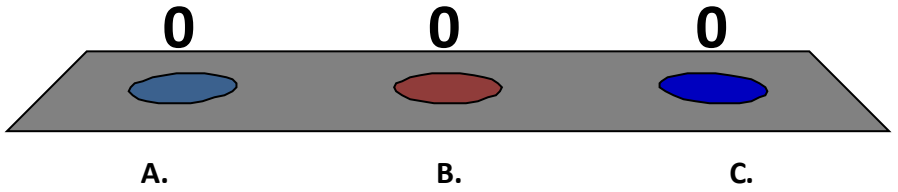
The treatment is established, effective, has few side effects and is affordable.

Do you opt for:

A. Giving it the drug

B. Not giving it the drug

C. Trying an herbal remedy that worked for a friend's pet



Your pet is sick

4 of 10 vets say it will die without treatment

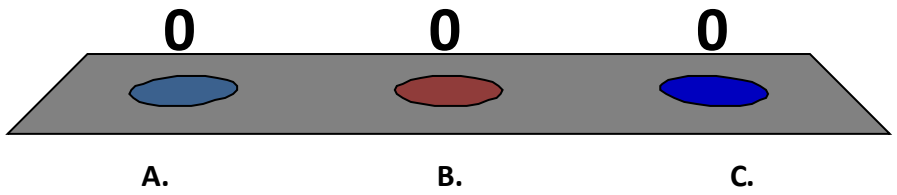
The treatment is established, effective, has few side effects and is affordable.

Do you opt for:

A. Giving it the drug

B. Not giving it the drug

C. Trying an herbal remedy that worked for a friend's pet



Your pet is sick

9 of 10 vets say it will die without treatment

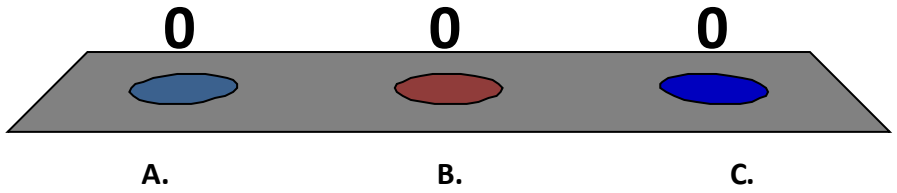
There is no proven treatment, but there's an expensive experimental drug with uncertain risks and effectiveness.

Do you opt for:

A. Giving it the drug

B. Not giving it the drug

C. Trying an herbal remedy that worked for a friend's pet



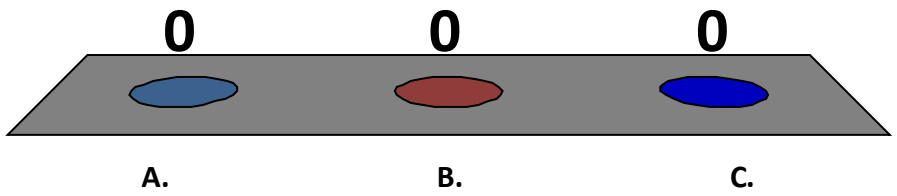
Your pet is sick

4 of 10 vets say it will die without treatment

There is no proven treatment, but there's an expensive experimental drug with uncertain risks and effectiveness.

Do you opt for:

A. Giving it the drug
B. Not giving it the drug
C. Trying an herbal remedy that worked for a friend's pet



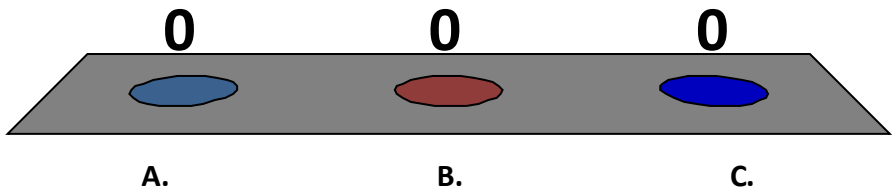
Your child is sick

9 of 10 doctors say she will die without treatment

There is no proven treatment, but there's an expensive experimental drug with uncertain risks and effectiveness.

Do you opt for:

A. Giving her the drug
B. Not giving her the drug
C. Trying an herbal remedy that worked for a friend's child



Putting Uncertainty in Context

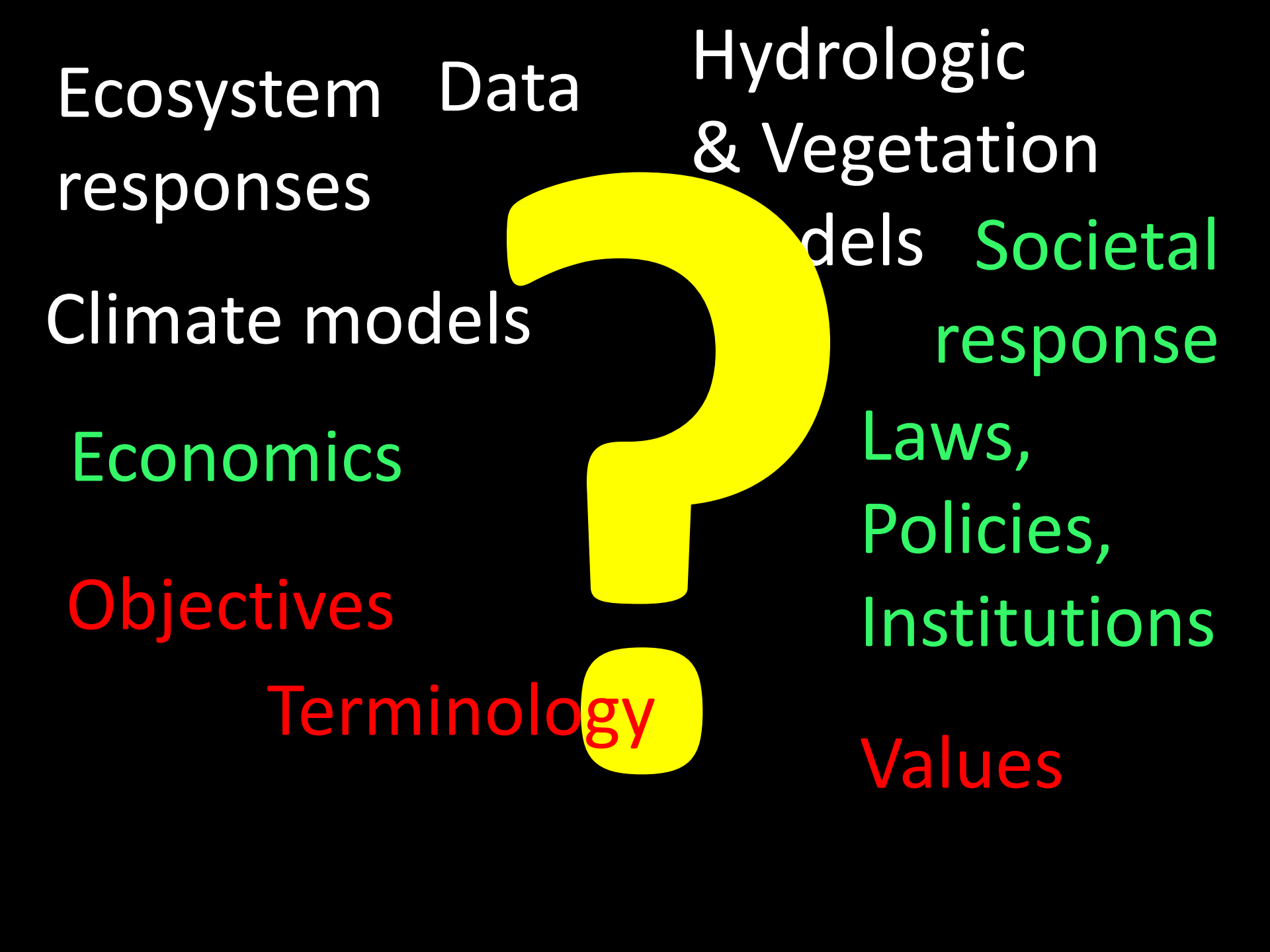
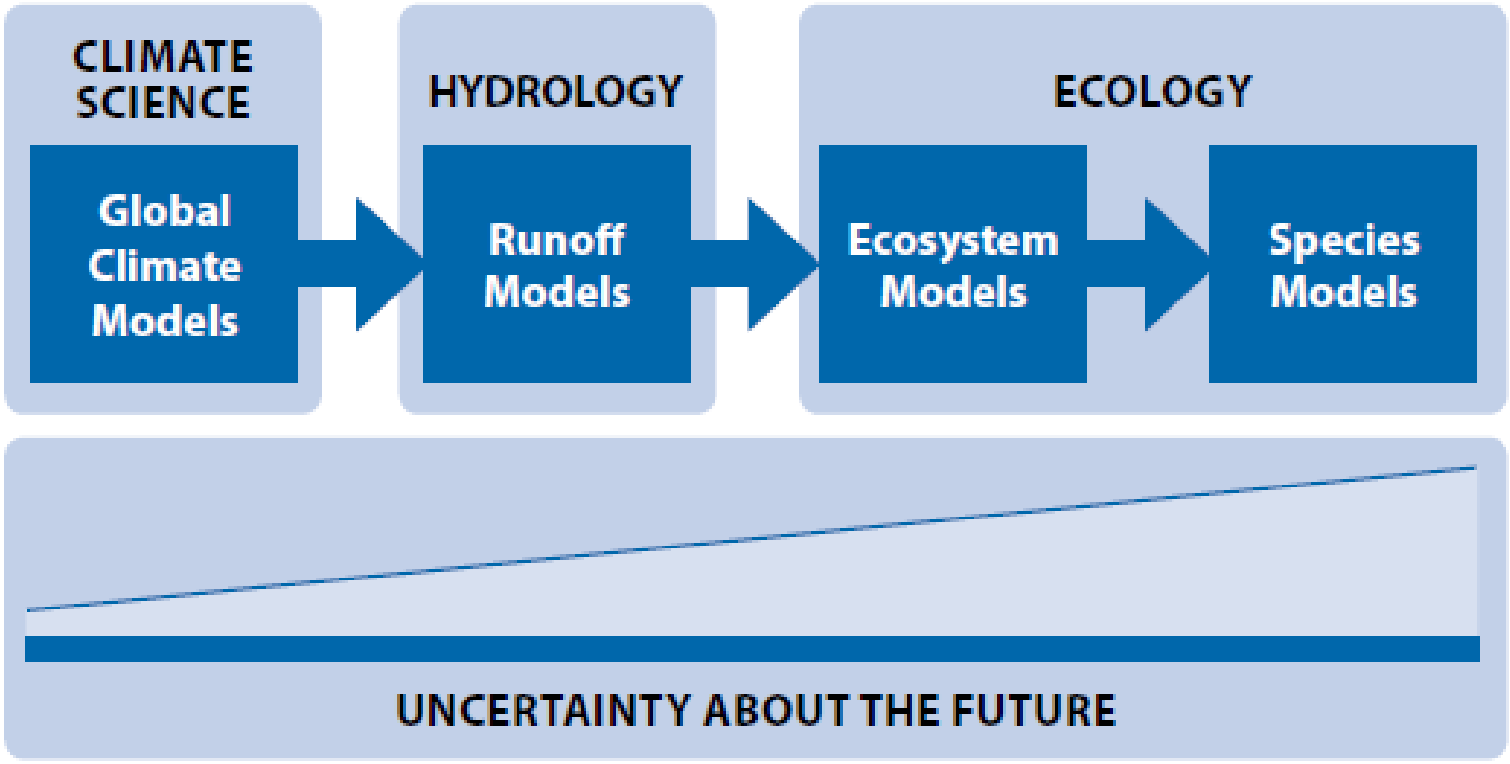

Ecosystem responses
Data
Hydrologic & Vegetation dels
Societal response
Climate models
Economics
Laws, Policies, Institutions
Objectives
Terminology
Values

Figure 2.3: Uncertainty about the future increases as results from uncertain models are combined. *Climate Change 2007: Synthesis Report*. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure 3.3. IPCC, Geneva, Switzerland..



Responses to uncertainty

Responses to uncertainty

- Ignore it/pretend you can get rid of it/wait and hope it goes away

Beware spurious precision!

The allure of downscaling

Beware spurious precision!

Certain: death and taxes

Uncertain: everything else

Responses to uncertainty

- Frame the problem as one of uncertainty

Responses to uncertainty

- Focus on better-understood problems where uncertainty seems manageable

Responses to uncertainty

- Understand and work with it

Uncertainty as information

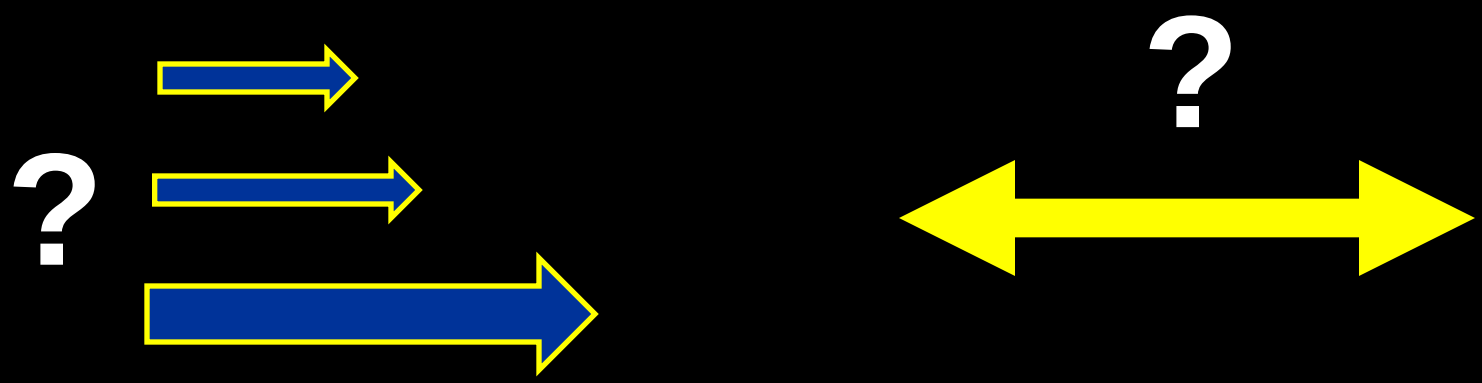
Being uncertain is not the same as knowing nothing

Characteristics:

- Reducibility

Characteristics:

- Reducibility
- Directionality vs. magnitude



Characteristics:

- Reducibility
- Directionality vs. magnitude
- Controllability

Characteristics:

- Reducibility
- Directionality vs. magnitude
- Controllability
- Decision relevance

Risk Attitude:

- Risk-averse vs. risk-seeking

Risk Attitude:

- Risk-averse vs. risk-seeking

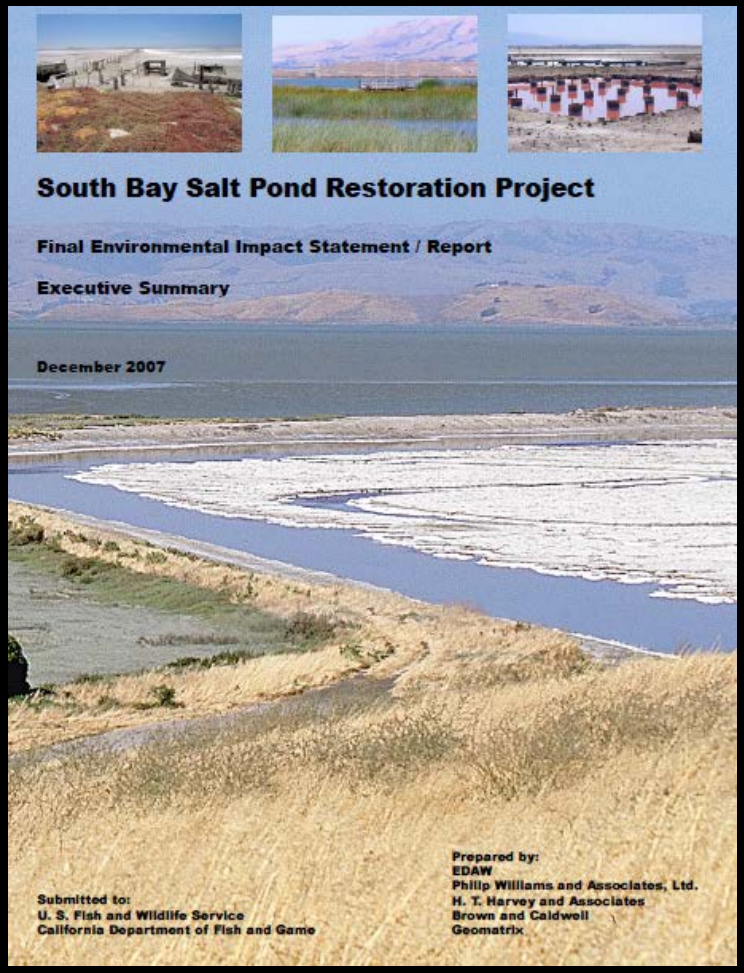
- Risk preference
  - Regret, robustness, expected payoff, loss and gain

Surf the wave!

- **Adaptive management**
- **Expert elicitation**
- **Scenario assessment**
- **Decision sensitivity analysis**
- **Value of information analysis**

Adaptive Management Plan for South Bay Salt Pond Restoration Project

- Specified **key uncertainties** and research to address them
- Specified **triggers** for action
- Specified necessary **science and institutional structure** for adaptive management to work



Really cool table!

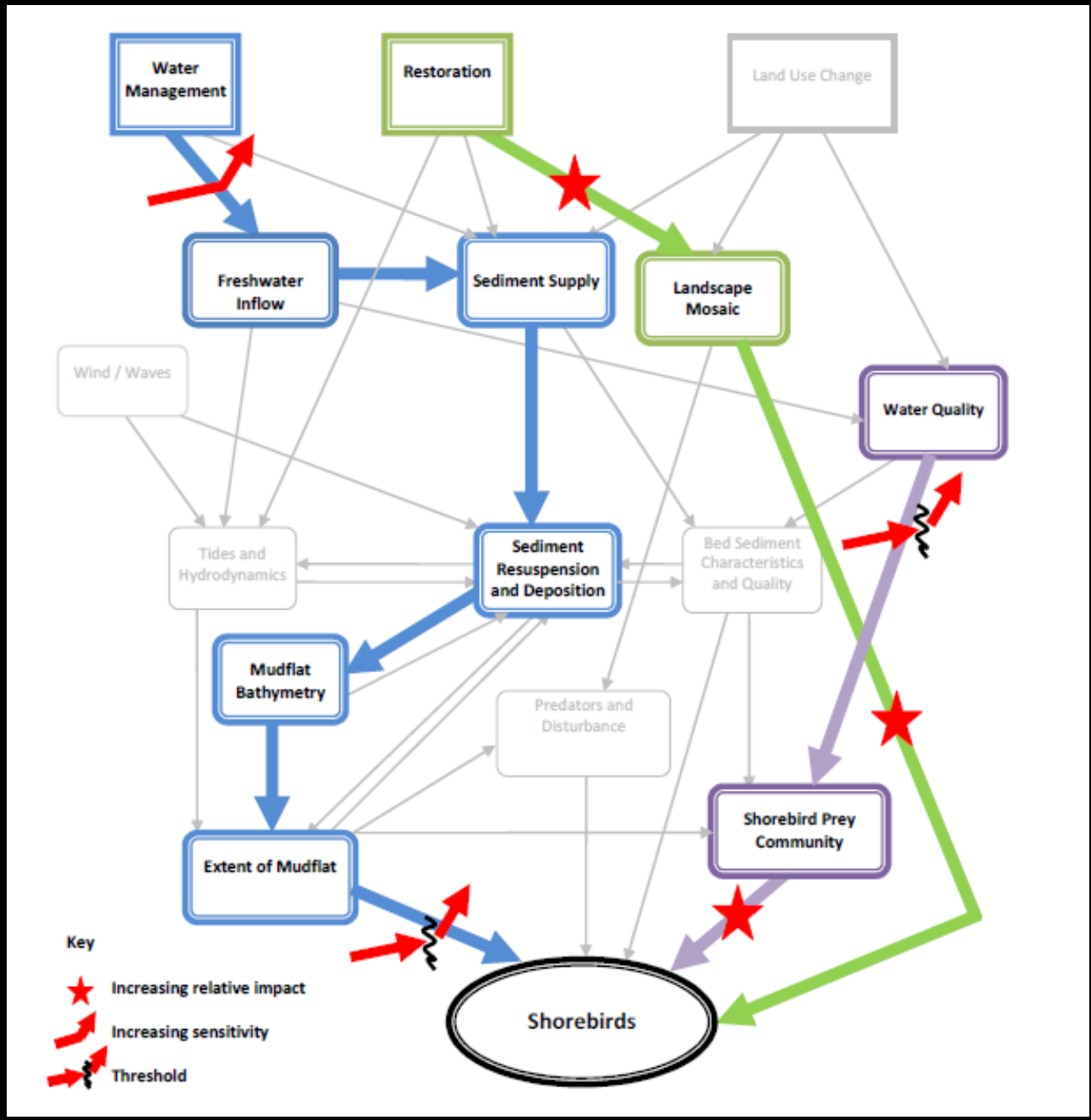
For each goal/target:

- What they'll monitor and where
- When they'll make decisions
- What observations would trigger a re-examination of their plans
- Action options once a trigger is tripped
- Key knowledge gaps and how they're filling them

MANAGEMENT TRIGGER	APPLIED STUDIES
▪ Outboard mudflat decreases greater than the range of natural variability + observational variability/error.	▪ Will sediment movement into restored tidal areas significantly reduce habitat area and/or ecological functioning (such as plankton, benthic, fish or bird diversity or abundance) in the South Bay? ▪ Development of a 2- and 3-D South Bay tidal habitats evolution model.

POTENTIAL MANAGEMENT ACTION
▪ Convene study session to review and interpret findings to assess if observed changes are due to restoration actions or system-wide changes in the sediment budget (*e.g.*, effects of sea level rise). ▪ Study biological effects of loss of mudflat, subtidal shallows, and/or subtidal channel habitat. ▪ Adjust restoration phasing and design to reduce net loss of tidal mudflats. Potential actions include remove bayfront levees to increase wind fetch and sustain tidal mudflat, phase breaching to match demand and supply, and/or breach only high-elevation ponds to limit sediment demand ▪ Reconsider movement up staircase

Climate Ready Estuaries "EE-type exercise"



Scenario assessment,

or

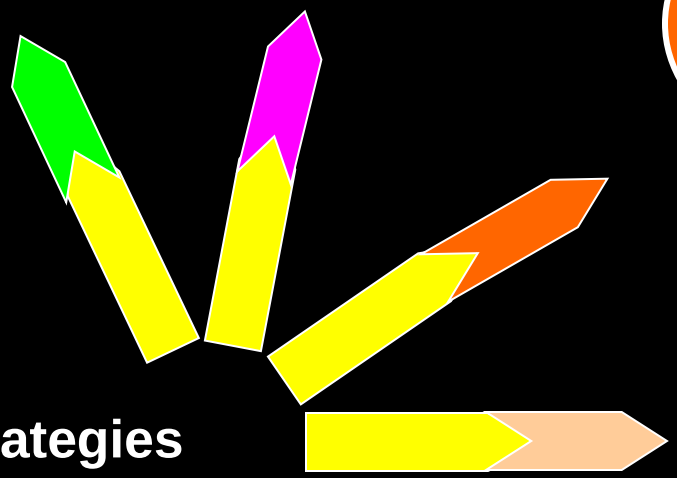
Should I buy this piece of property?

Scenario 1: It's unaffected by climate change

Scenario 2: All listed species disappear

Scenario 3: It becomes a key refugial habitat

Contingent actions/strategies



Core actions/strategies

Scenario 4: The habitat type changes

Driving forces-Categories (STEEP)

Category	Drivers
Environmental	Climate change Air and water pollution Invasive non-native species Environmental policy
Economic	Economic growth Commondity prices Demand and consumption patterns Income and distribution Market development
Political	Macroeconomic policy Land-use plans, zoning, management Governance and corruption Property rights and land tenure
Social & Demographic	Population growth/decline Migration Cultural values Education Religious values
Technological	Technological innovation Technology choice

E

E

P

S

T

Examples of Climate Change-Related Drivers

Frequency & magnitude of drought, flood

Changes in seasonal patterns of rain & snow

Sea level rise

Storm surge, erosion and washover

Frequency of extreme events

Example: Tidal marsh restoration SF Bay with sea level rise

- Sea level rise
- Sedimentation

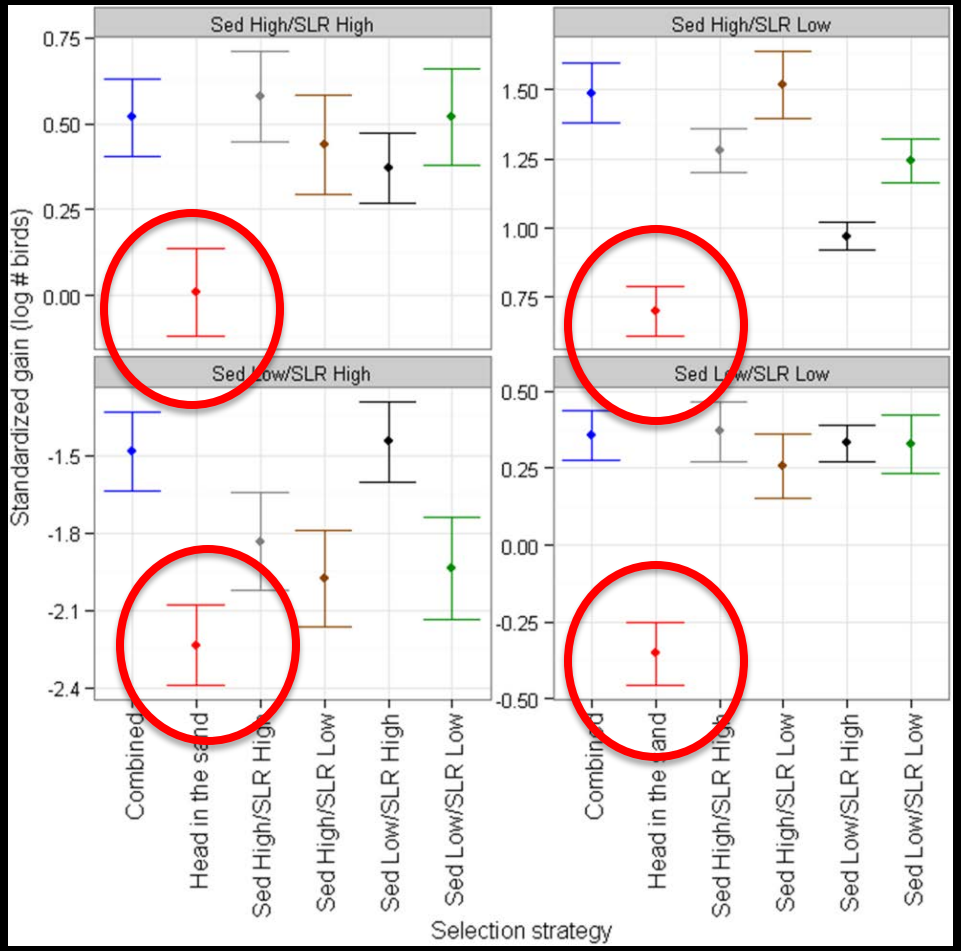
Four scenarios:

- H/H
- H/L
- L/L
- L/H

SF Bay: Assessing Impacts

of birds added with restoration projects in each scenario

Evaluating different project selection strategies



Veloz et al. 2013. Ecosphere

Take-home message

Dealing with uncertainty in management can be hard;

Not dealing with it can be much harder

EXTRA SLIDES

Expected Value, Minimum Payoff, & Robustness

Action	Outcome				EV	Maxi-Min	P>15
	0	10	20	30			
A	.25	.25	.25	.25	15	0	50%
B	.00	.25	.50	.25	20	10	75%
C	.10	.20	.00	.70	23	0	70%
D	.20	.00	.80	.00	16	0	80%

Estimating degree of uncertainty

- Monte Carlo
- Bayesian

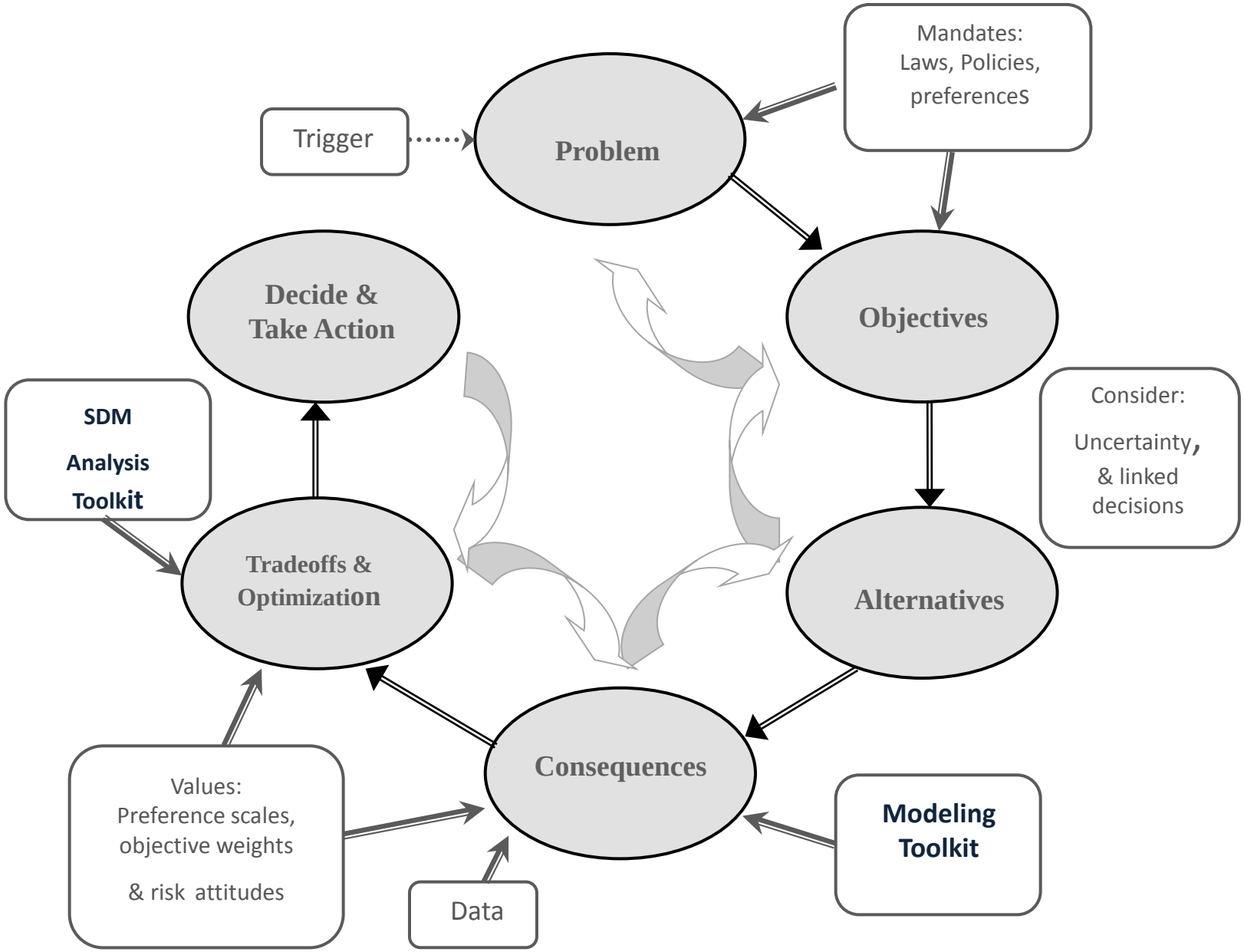
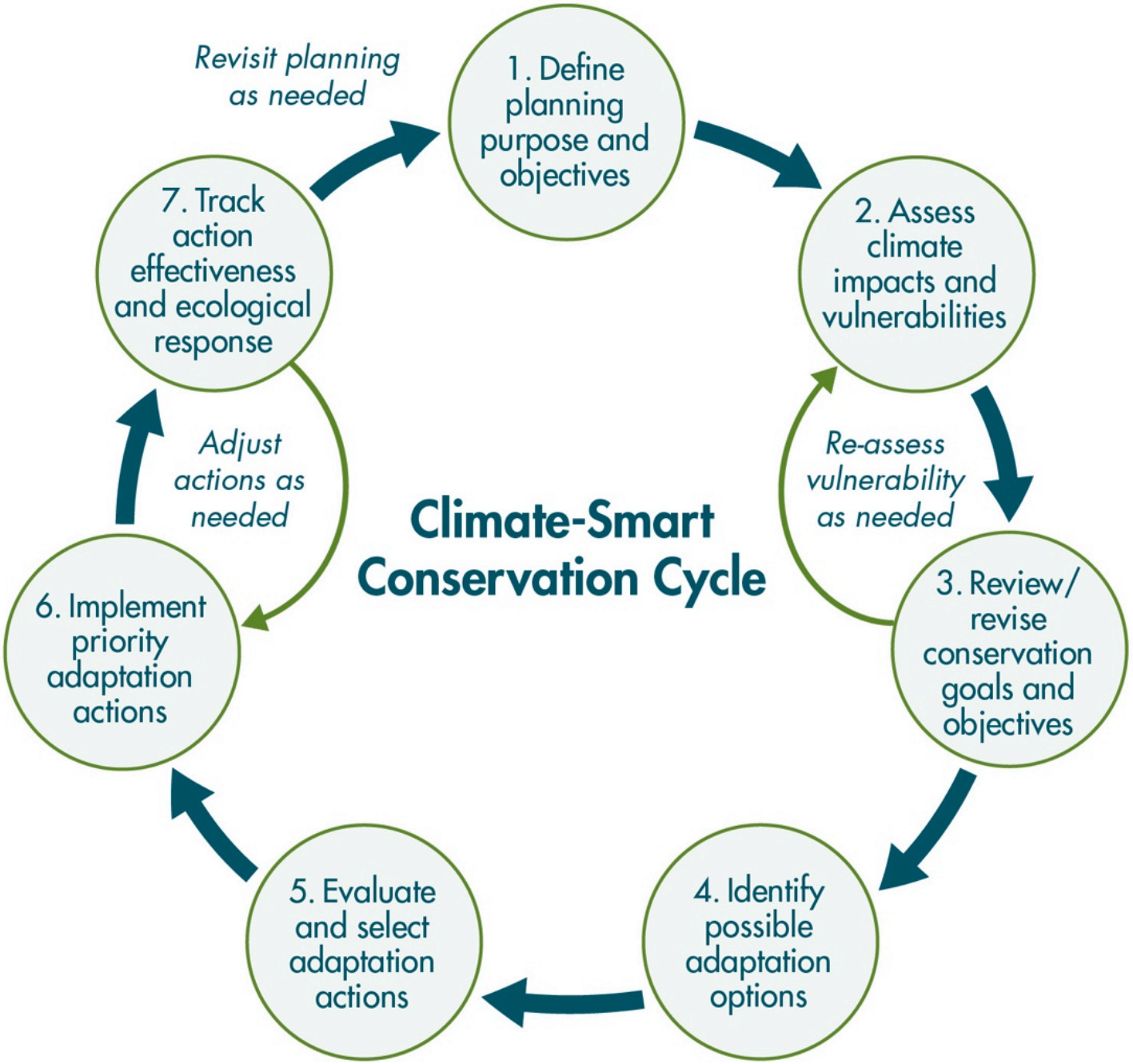


Illustration by Jean Cochrane


Climate-Smart Conservation Cycle
1. Define planning purpose and objectives
2. Assess climate impacts and vulnerabilities
3. Review/ revise conservation goals and objectives
4. Identify possible adaptation options
5. Evaluate and select adaptation actions
6. Implement priority adaptation actions
7. Track action effectiveness and ecological response
Revisit planning as needed
Re-assess vulnerability as needed
Adjust actions as needed

Known unknowns vs. Unknown unknowns

- Scenario planning, SDM can help build clarity and flexibility
- Describe/characterize uncertainty
  - Importance to decision?
  - Reducibility? Quantifiability?
  - Content: resource responses, sociological responses, synergistic effects

"It is hard for us, and without being flippant, to even see a scenario within any realm of reason that would see us losing $1 in any of those transactions."

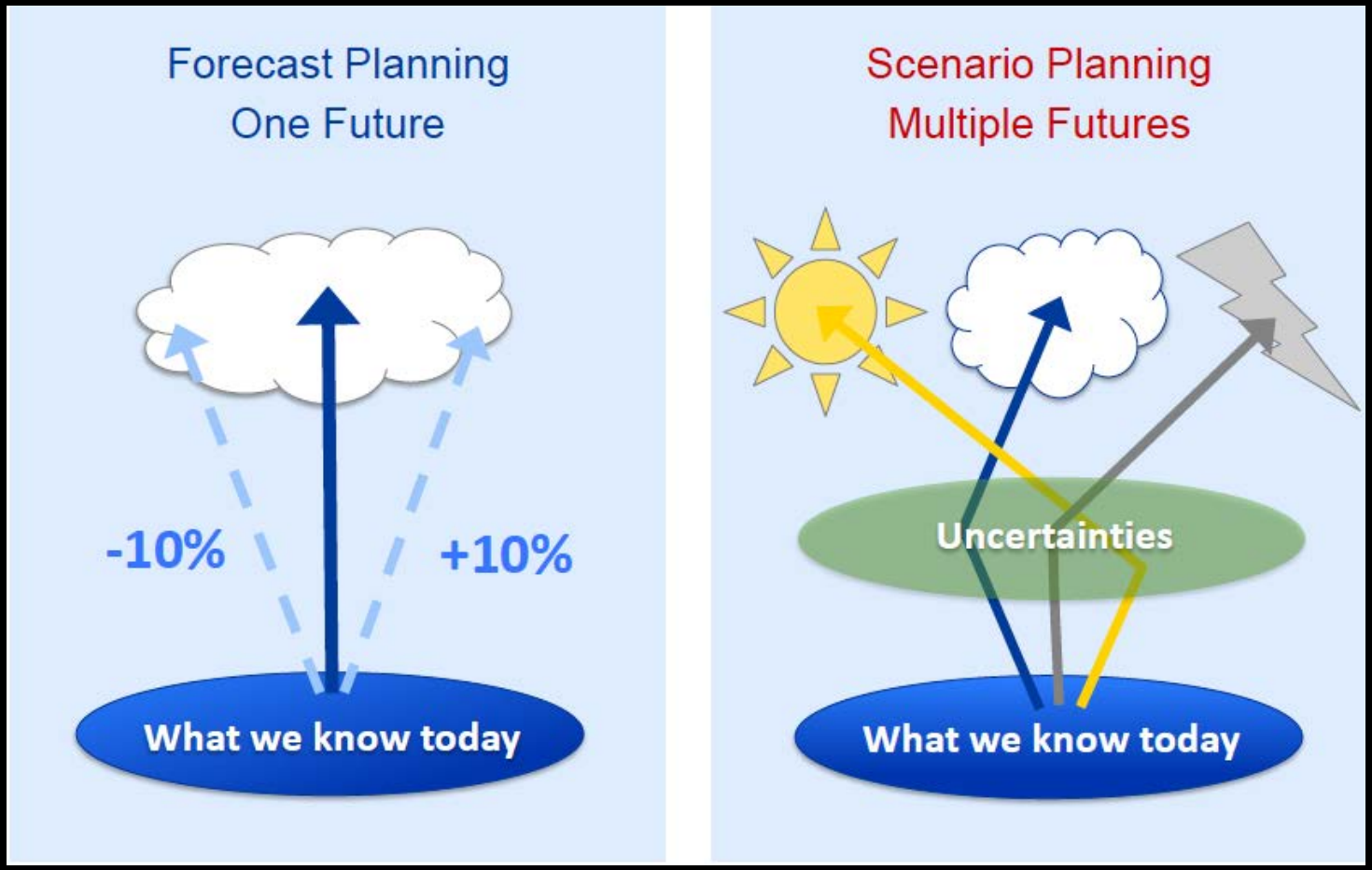
– Joseph Cassano
Head of AIG Financial Products, August 2007

May I have the ability to reduce the uncertainties I can, the willingness to work with the uncertainties I cannot, and the scientific knowledge to know the difference.

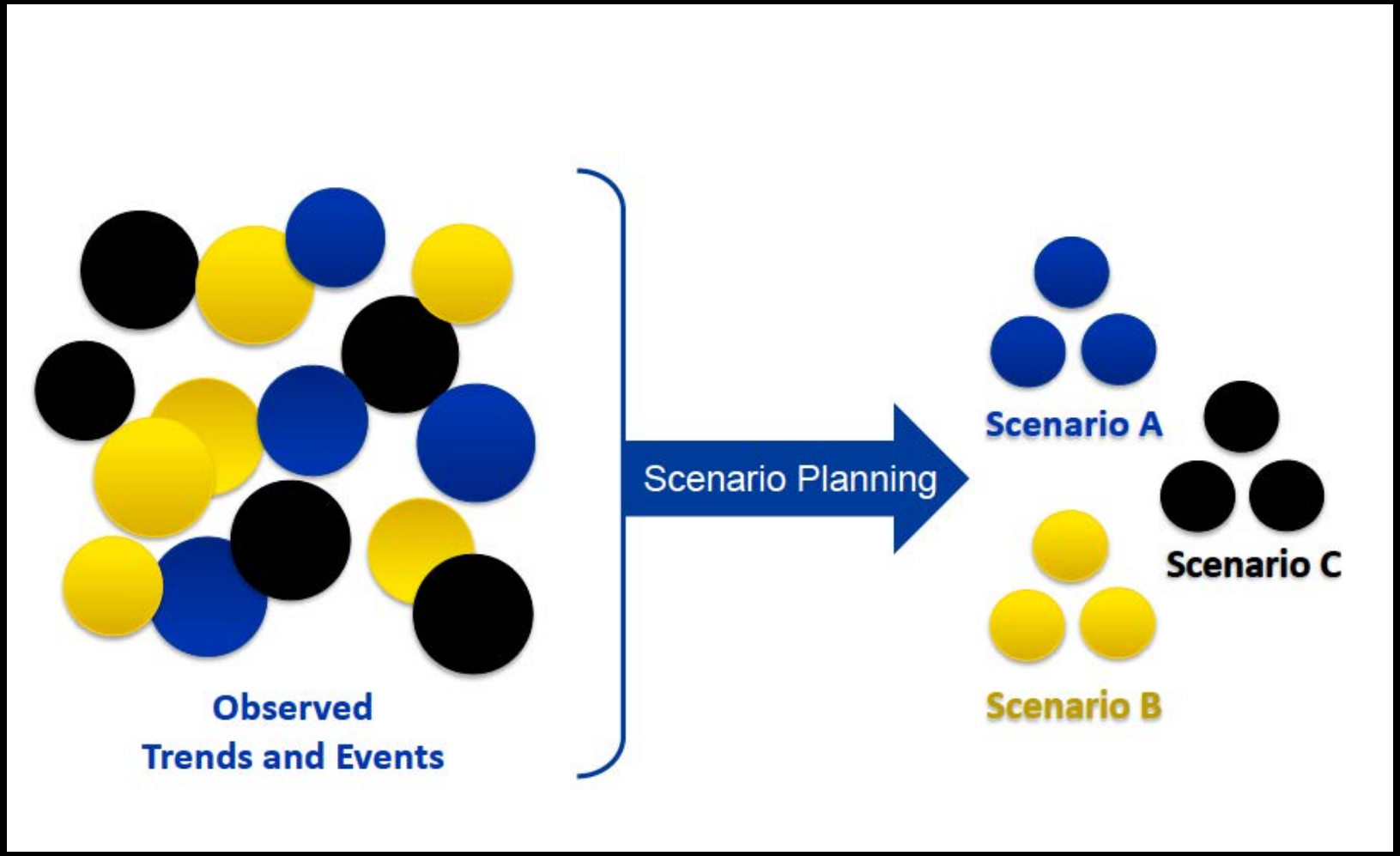
Joe Barsugli, Cheis Anderson, Joel Smith and Jason Vogel

Scenario Planning vs. Forecasting

“Never make forecasts, especially about the future.” (Samuel Goldwyn)



GBN


Observed
Trends and Events
Scenario Planning
Scenario A
Scenario C
Scenario B

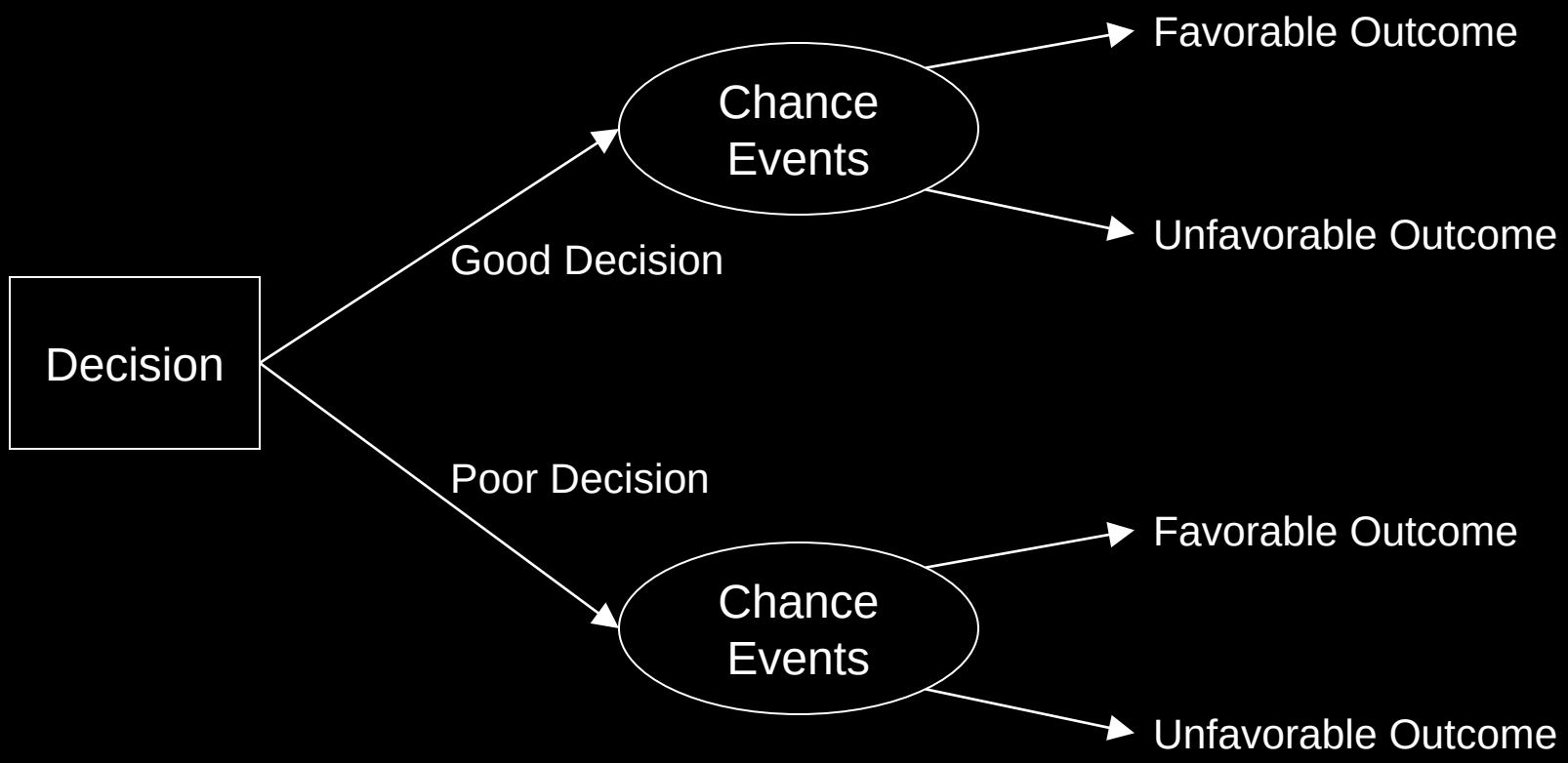
GBN

The dangers of uncertainty

"…unacknowledged uncertainty leads to ***optimistic expectations*** *that cannot be satisfied, to the* ***misdirection of scarce conservation resources****, and to actions that are blind to substantial qualitative and quantitative uncertainties that,* ***if they were apparent, would lead to different decisions****…"*

- Burgman et al. (2005)

A good decision?



Linguistic uncertainty

- Vagueness
  - Language permits borderline cases
- Context dependence
  - Meaning depends on context
- Ambiguity
  - Words can have more than one meaning
- Underspecificity
  - Unwanted generality in statements
- Indeterminacy of terms
  - Understanding of terms changes over time

Epistemic uncertainty

- There is a fact, but we don’t know it exactly
- Reducible
- Sources
  - Measurement error
  - Systematic error (bias)
  - Model uncertainty
    - Parametric uncertainty
    - Structural uncertainty
  - Subjective judgment

Aleatory uncertainty

- Practically irreducible
- Environmental stochasticity
  - Natural variation in systems over space and time that is difficult to predict
- Demographic stochasticity
  - The chance events that happen to individuals (may affect survival, reproduction).

Sensitivity Analysis

- Examine how the optimal decision and the expected performance are affected by
  - Assumptions
  - Structural & parametric uncertainty
  - Probabilities
  - Magnitude of uncertainty
  - Weights on objectives
  - Utility
  - The problem framing itself

- Ask whether the decision is robust to uncertainty
  - If not, consider revising aspects of the problem

Emphasis

- Examine how
  - the optimal decision and
  - the expected performance
- are affected by…

- That is, *would your decision change*?