Decision Analysis for Support of Management and Research in the Glen Canyon Dam Adaptive Management Program

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Technical Working Group Meeting,

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U.S. Department of the Interior
U.S. Geological Survey

Presentation Overview

- Background:
  - Natural resource decisions – why they are difficult
  - How decision analysis can help confront complexities and uncertainties
- Tools and methods:
  - Decision analysis (aka "structured decision making")
  - PrOACT – model of decision analysis
  - Value of information – a sensitivity analysis for decision makers
- Demonstration of rapid prototyping approach to decision analysis –
  - California Central Valley Project water releases, spring 2025
- Discussion of potential Glen Canyon Dam Adaptive Management Program (GCDAMP) applications

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Water management decision-making

"People thinking hard about a water management decision"

Image generated using
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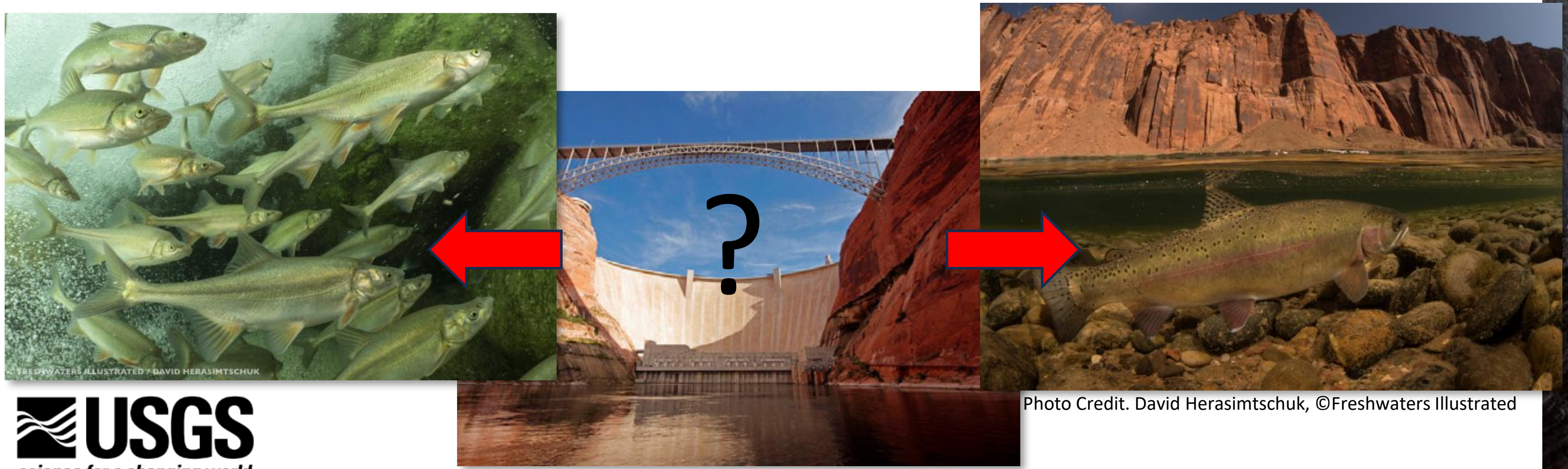
Background

- River management decision-making is difficult – due to tradeoffs and uncertainty!
  - Requires placing weights (priorities) on resource objectives or values
  - Uncertainty in predictions increases difficulty in decision-making



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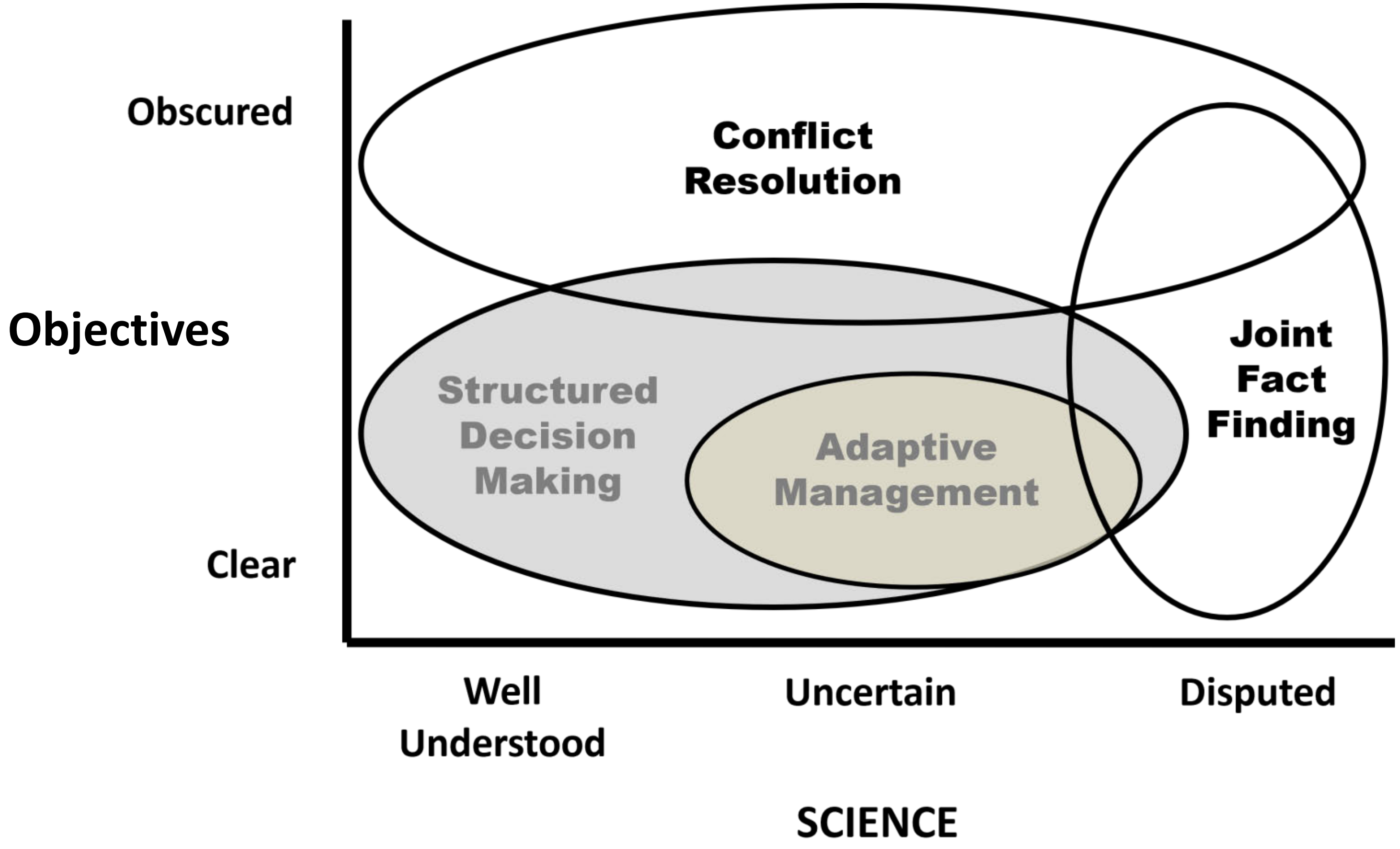
Background

- What is decision analysis?
  - A way of thinking - <u>value-focused</u>
  - Guards against human cognitive biases – e.g., anchoring
  - Breaking down difficult problems into components for deliberation
  - Provides clear roles for policy and science
  - Helps identify and prioritize uncertainties <u>relevant to decision-making</u> (not all scientific uncertainties are important to a decision)
  - Can be rapid – it does not necessarily require a large amount of time or money
  - Transparent (<u>how</u> a decision is made may be as important as the decision itself)

When is Structured Decision Making appropriate?



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Runge, et al. (2013)

Decision Analysis Tools

- Decomposing difficult decisions into components – PrOACT
- Pr – define the problem
- O – define objectives and performance metrics
- A – develop alternatives
- C – consequences
- T – evaluate tradeoffs

- PrOACT

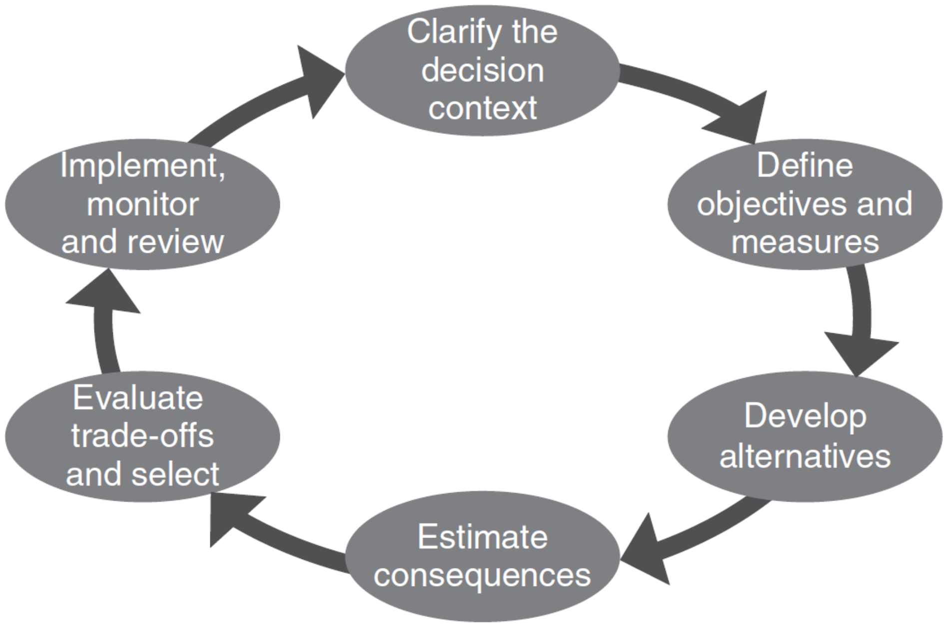

Figure 1.1 Steps in structured decision making.

Gregory et al. 2012

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Value of Information (VOI)

- Identify sources of uncertainty impeding decisions – will the decision change depending on which ecological hypothesis is true?
  - What research and monitoring is most important for decision-making?
- VOI - “Expected value of perfect information”
  - Measured in terms of the objectives important to a decision maker –
    - how much improvement (%) in outcomes can be achieved if I reduce uncertainty before making a decision?
- Decision analysis tool to address types of information problems –
  - Making a decision vs. delay to gather more information
  - Monitoring design
  - Identify and prioritize research
  - Adaptive management – improve later decisions

Water Management-California's Central Valley

- Decision analysts included:
  - Brian D. Healy
  - Corey C. Phillis, The Metropolitan Water District of Southern California
  - Brian Mahardja, U.S. Bureau of Reclamation
- Timeframe for completion:
  - February 13-March 26
  - Implementation, summer 2025


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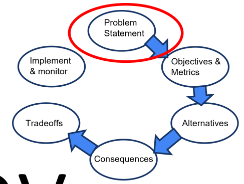
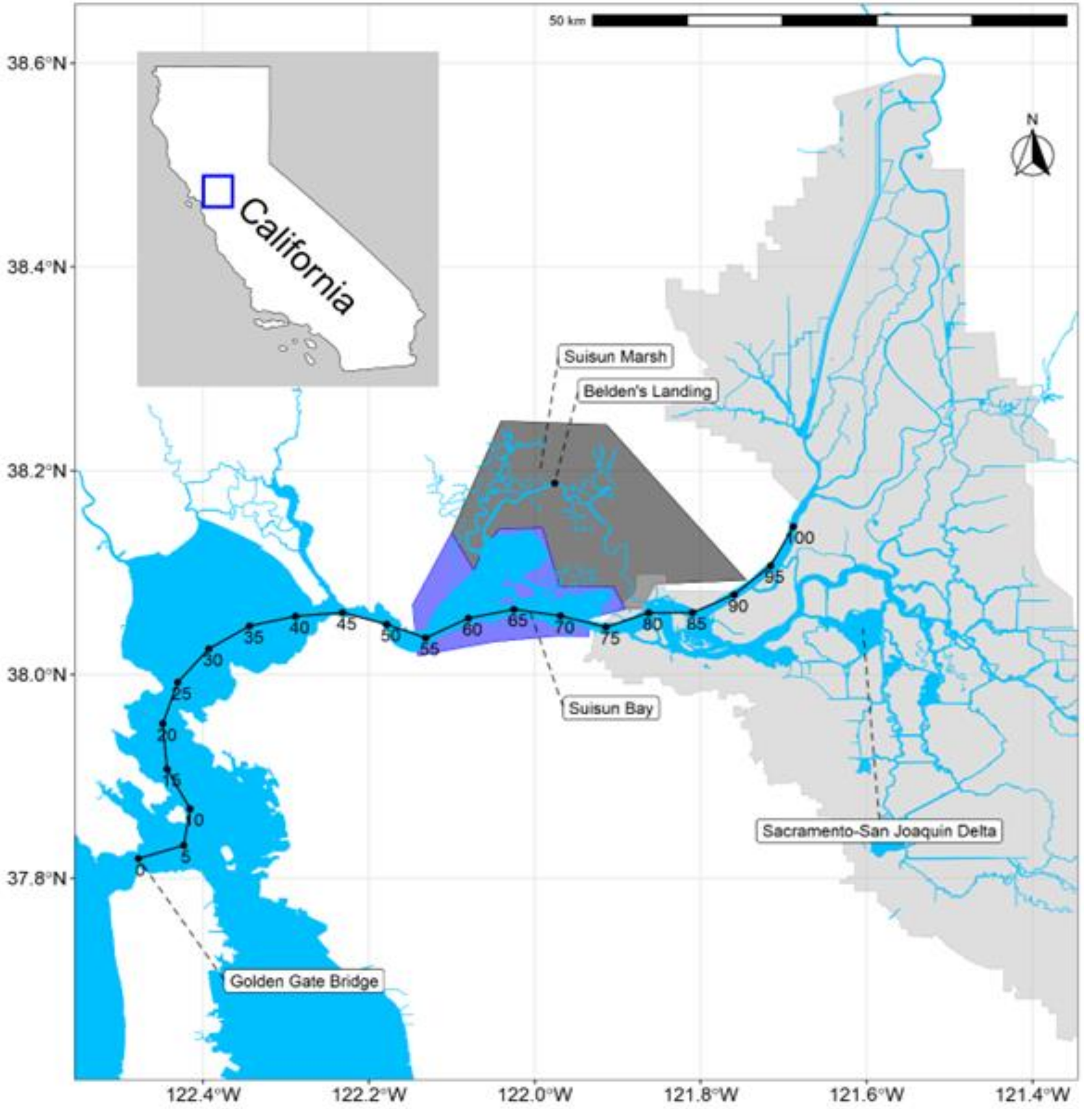
Water Management-California's Central Valley



- Problem:
  - Continued declines in Delta Smelt
    - 2024 Biological Opinion- consider summer flow actions
  - Executive Orders – "maximize water supply"
  - Consider releases of water from reservoirs to meet objectives in the Sacramento-San Joaquin Delta
    - Multiple water supply-related objectives
  - Involved 8 decision makers and stakeholders in decision process
    - Used GCDAMP SDM as a model



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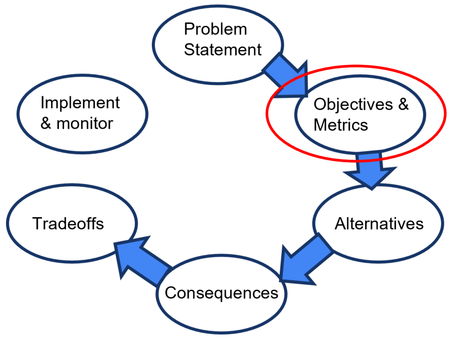
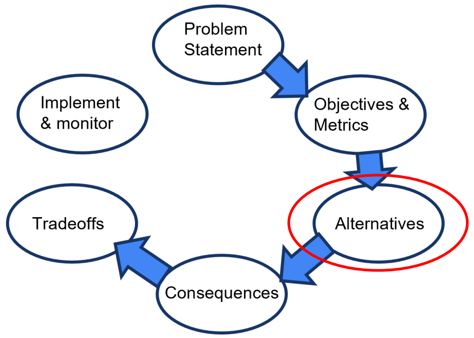
Objectives - What We Care About



- Fundamental objectives analyzed (performance metrics)
  - Water Supply-State Water Project (SWP; maximize exports)
  - Water Supply-Central Valley Project (CVP; maximize exports)
  - Delta Smelt persistence (maximize minimum abundance, 400-500k required for broodstock)
  - Water quality and human health (maximize-constructed scale using conductivity at Jersey Point)
- Objectives analyzed to address consequences to other listed species or address risk to water operations
  - Winter-run Chinook Salmon (minimize redd dewatering)
  - Steelhead (maximize probability of Folsom Lake storage volume >300 thousand acre-feet in December 2025)
  - Coldwater pool/storage volume for salmonids-CVP (maximize probability of April 2026 storage in Shasta Lake ≥ 3.7 million acre-feet)
  - Coldwater pool/storage volume for salmonids-SWP (maximize probability of September 2025 storage in Oroville Lake ≥ 1.85 million acre-feet)

Data source: Healy et al. 20205, DOI: [10.5066/P13BBC7D](https://doi.org/10.5066/P13BBC7D)

Alternatives



1. Status quo – 2024 record of decision flows, fall X2 at 80km (X2= the location of the low salinity zone)
2. Maximize Delta Smelt- evenly distributed summer flow with fall X2 at 74 km
3. Maximize Delta Smelt- summer flows similar to historic, June peak flow and summer recession with fall X2 at 74 km
4. Summer-Fall even flow – Evenly distributed summer flow and fall X2 at 80 km
5. Summer-Fall historic – summer flow with peak in June, and fall X2 at 80 km
6. Summer even flow – Evenly distributed summer flow, no fall X2
7. Summer historic – June peak flow and summer recession, no fall X2
8. Summer even flow/modified salinity control gate action, no fall X2
9. June action – minimize duration of summer flow, no fall X2
10. Maximize water supply – minimum flows for water quality standards, incl. salinity control gate
11. Maximize water supply, no salinity control gate action – minimum flows for water quality standards

*Note: we were unable to finalize non-flow action modeling workflow on our timeline – weed control alternatives could not be analyzed.

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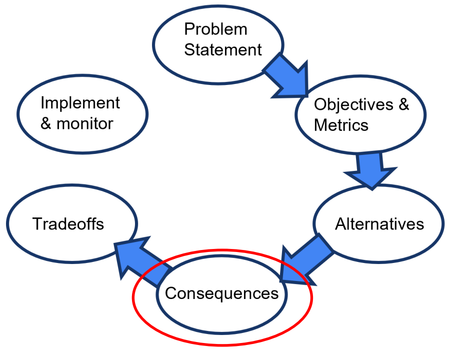
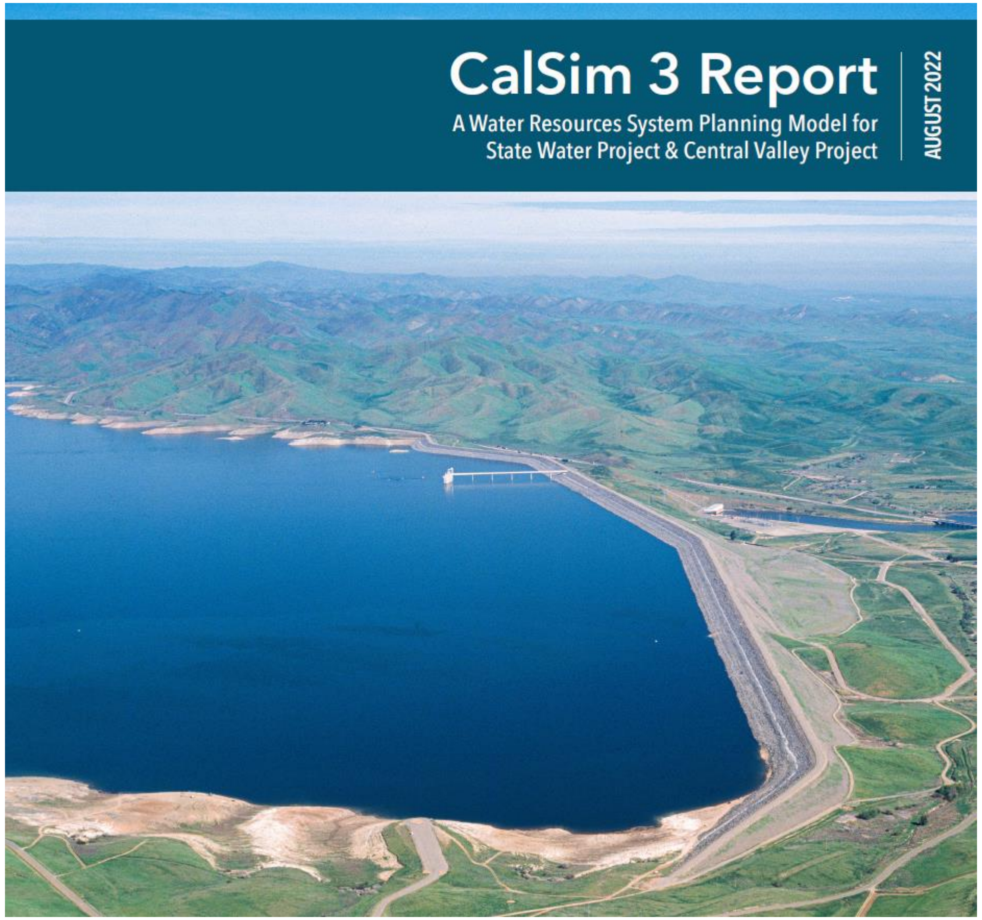
Data source: Healy et al. 20205, DOI: 10.5066/P13BBC7D

Consequences – Predictive Modeling



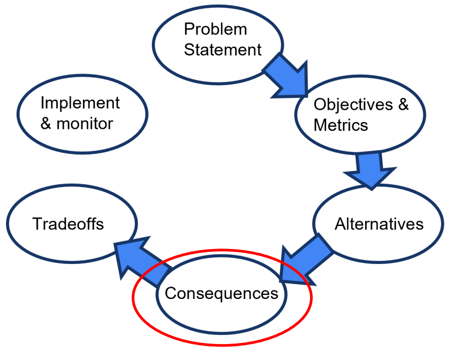
- Modeling approach – used available models
  - CalSim 3 with competing models of baseline hydrology
    - Model favored and used by Ca. Dept. of Water Resources (CA-DWR) vs. model used by Reclamation
    - Value of information – do baseline hydrology assumptions change the alternative ranking?
  - Delta Smelt Individual Based Model in R (IBMR)
  - Winter-run Chinook Salmon redd dewatering model



California Department of Water Resources, 2022

Consequences – Averaged Across Models

*Assumes equal belief in baseline hydrology models



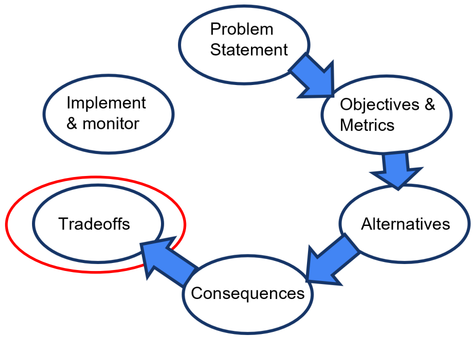
Alternative	Delta Smelt	Water Supply-CVP exports	Water Supply-SWP exports	Winter-run Chinook redd dewatering	Steelhead	Water Quality and Human Health	Coldwater pool for salmonids-CVP	Coldwater pool for salmonids - SWP
Status quo	84,162	2,259	2,894	0.058	0.975	0.873	0.818	0.878
Max.Delta Smelt Even Flow	1,709,081	2,107	2,511	0.190	0.850	0.948	0.687	0.402
Max.Delta Smelt Historic	1,834,144	2,104	2,543	0.124	0.838	0.948	0.687	0.390
Summer-Fall Even Flow	54,351	2,233	2,826	0.109	0.963	0.919	0.793	0.878
Summer Fall Historic	39,297	2,237	2,828	0.091	0.963	0.882	0.793	0.878
Summer Even Flow	101,859	2,287	2,969	0.109	0.963	0.815	0.808	0.841
Summer Historic	83,639	2,290	2,964	0.126	0.988	0.780	0.808	0.854
Summer Even Flow Alt. SMSC Gate action	100,257	2,287	2,969	0.109	0.963	0.815	0.808	0.829
June Action only	42,550	2,299	2,973	0.108	1.000	0.781	0.838	0.927
Maximize Water Supply	56,810	2,298	2,999	0.098	1.000	0.780	0.828	0.939
Max. Water no SMSC Gate action	49,239	2,295	2,999	0.101	1.000	0.778	0.833	0.951

CVP=Central Valley Project, SWP=State Water Project, SMSC=Suisun Marsh Salinity Control

Performance scale:

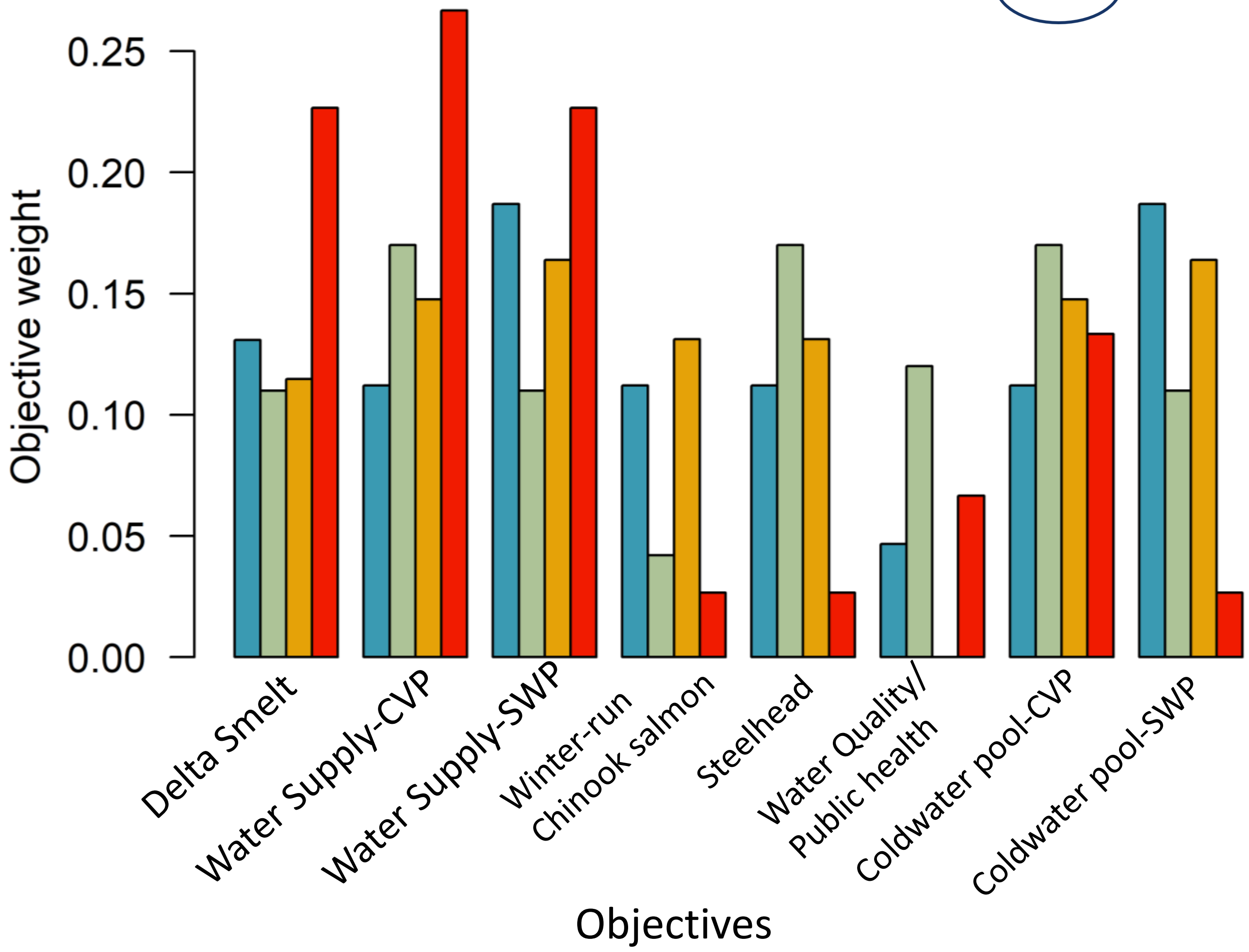
Worst Best

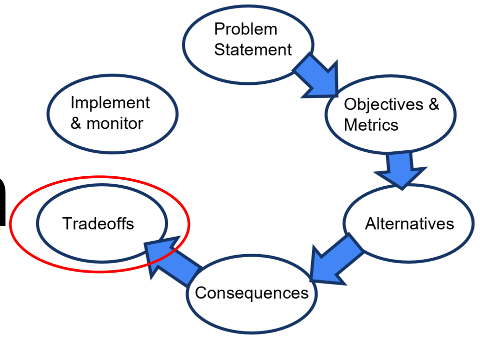
Data source: Healy et al. 20205, DOI: 10.5066/P13BBC7D



Tradeoffs: Objective Weights

- Swing weighting
  - Involves putting weight on objectives relative to their importance to the decision maker, and
  - considering the range of consequences across the alternatives
- Objective weights provided by 4/8 participants (represented by colors)
  - Reclamation, CA-DWR, 2 anonymized participants





Composite Score and Ranks -Reclamation

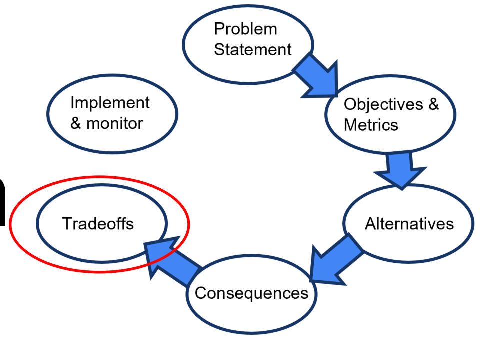
- Alternative ranks by composite utility score

  *equal belief in hydrology models

Rank	Alternative	Composite score
1	Maximize Water Supply	0.658
2	Maximize Water Supply no SMSCG	0.657
3	June	0.655
4	Summer-Even Flow	0.629
5	Summer Even Flow Alt.SMSCG	0.629
6	Summer Historic	0.616
7	Status Quo	0.613
8	Summer-Fall Even Flow	0.547
9	Summer-Fall Historic	0.54
10	Max. Delta Smelt Historic	0.403
11	Max. Delta Smelt Even Flow	0.373

SMSCG=Suisun Marsh Salinity Control Gate

Composite Score and Ranks -Reclamation



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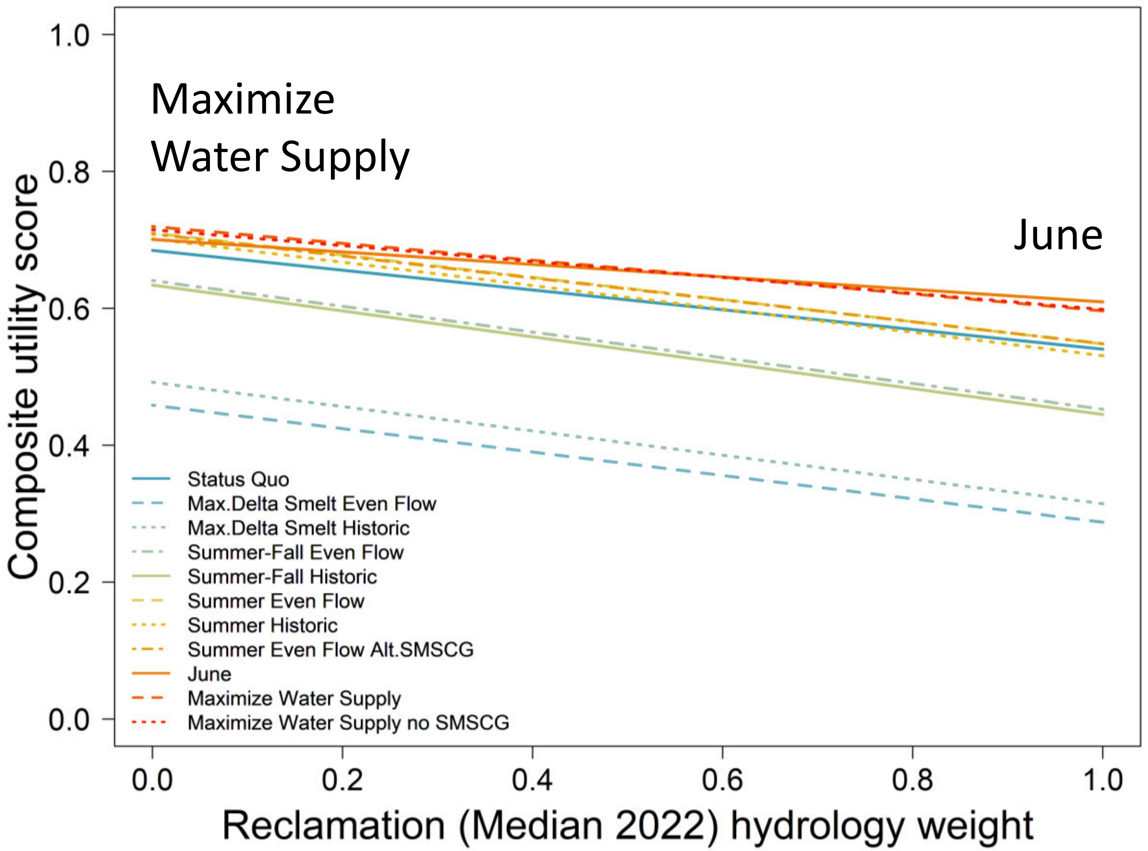
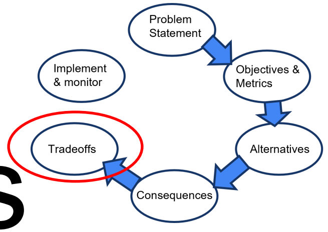
SMSCG=Suisun Marsh Salinity Control Gate

- Value of information <1%



Multi-criteria Decision Analysis Scores



- Final composite scores, by participant:
  - Green=highest ranked alternative, pink=lowest ranked alternative

Number	Alternative	CA-DWR	Reclamation	Participant B	Participant C
1	Status Quo	0.721	0.613	0.725	0.753
2	Max. Delta Smelt Even Flow	0.306	0.373	0.364	0.257
3	Max. Delta Smelt Historic	0.36	0.403	0.38	0.317
4	Summer-Fall Even Flow	0.642	0.547	0.677	0.649
5	Summer-Fall Historic	0.647	0.54	0.66	0.666
6	Summer-Even Flow	0.679	0.629	0.681	0.72
7	Summer Historic	0.673	0.616	0.674	0.722
8	Summer Even Flow Alt.SMSCG	0.676	0.629	0.679	0.717
9	June	0.735	0.655	0.735	0.793
10	Maximize Water Supply	0.746	0.658	0.733	0.802
11	Maximize Water Supply no SMSCG	0.747	0.657	0.735	0.803

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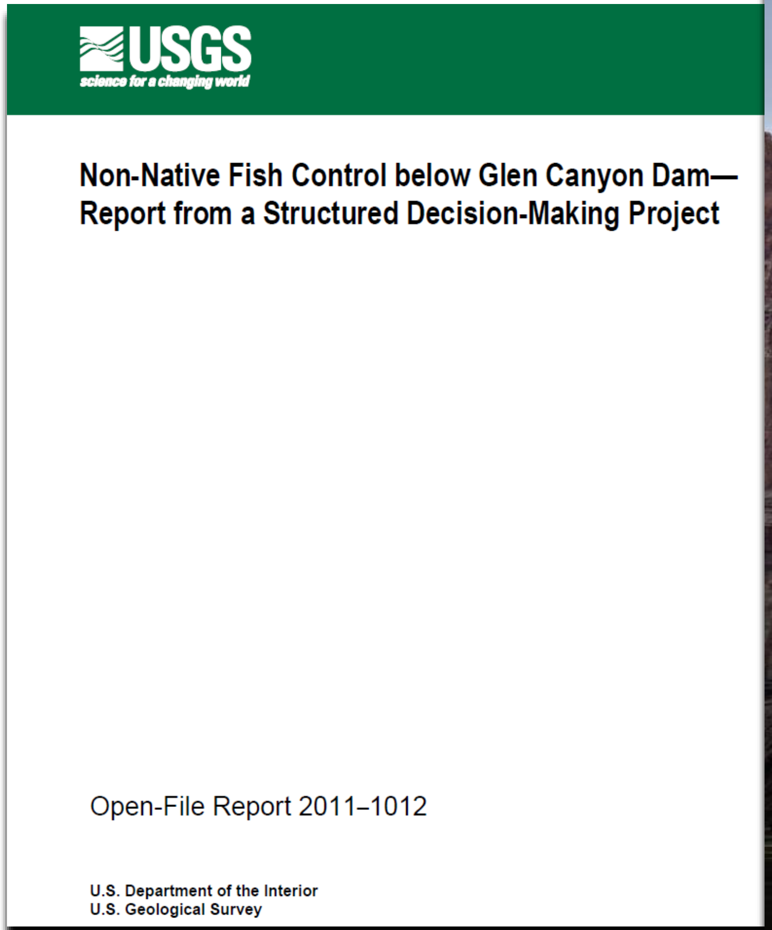
Data source: Healy et al. 2025, DOI: 10.5066/P13BBC7D

Summary and Discussion

- Top 1-3 alternatives consistent across participants
- Objective weighting process
  - Difficult value tradeoffs became clear to participants (it wasn't about "the science")
- Modeling uncertainty
  - Baseline hydrology – alternative ranks sensitive to hydrology but generally only slight differences among top 3 alternatives' composite scores
  - Limited value of information (<1% improvement would be expected after reducing uncertainty)

Decision Analysis and the GCDAMP



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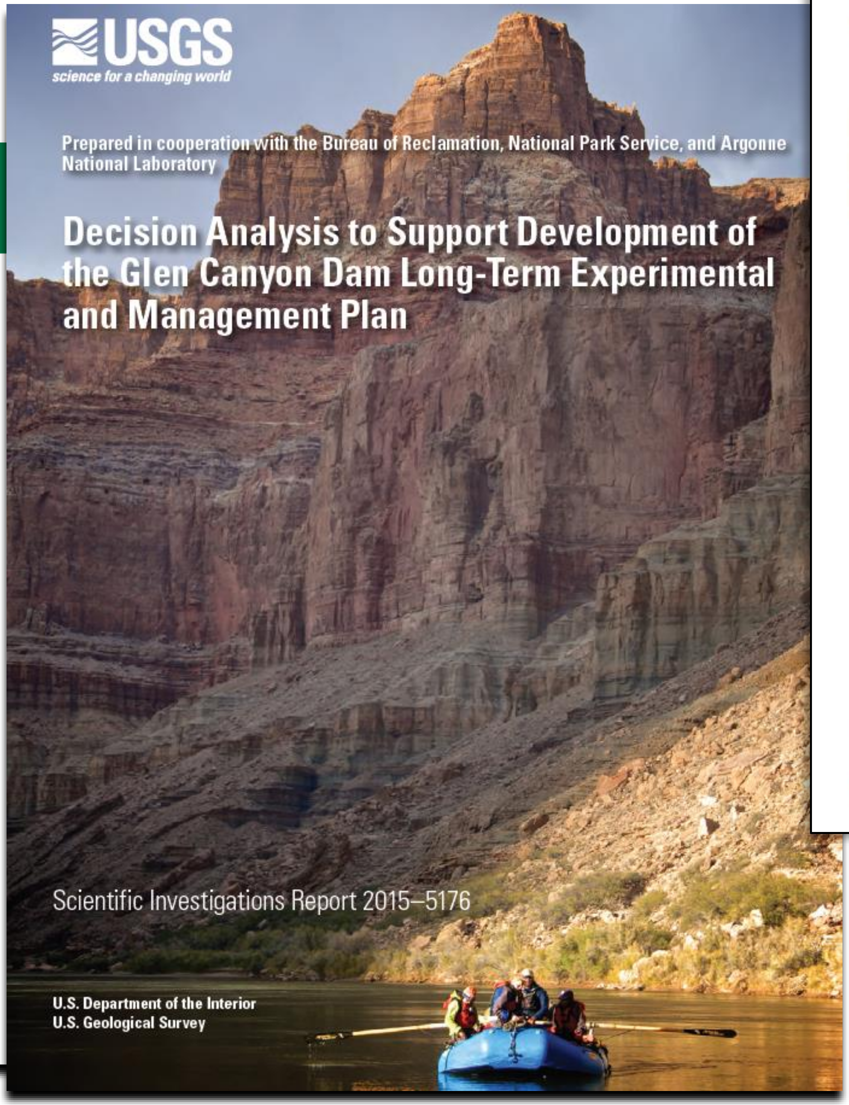
Non-Native Fish Control below Glen Canyon Dam—Report from a Structured Decision-Making Project

Open-File Report 2011–1012

U.S. Department of the Interior
U.S. Geological Survey



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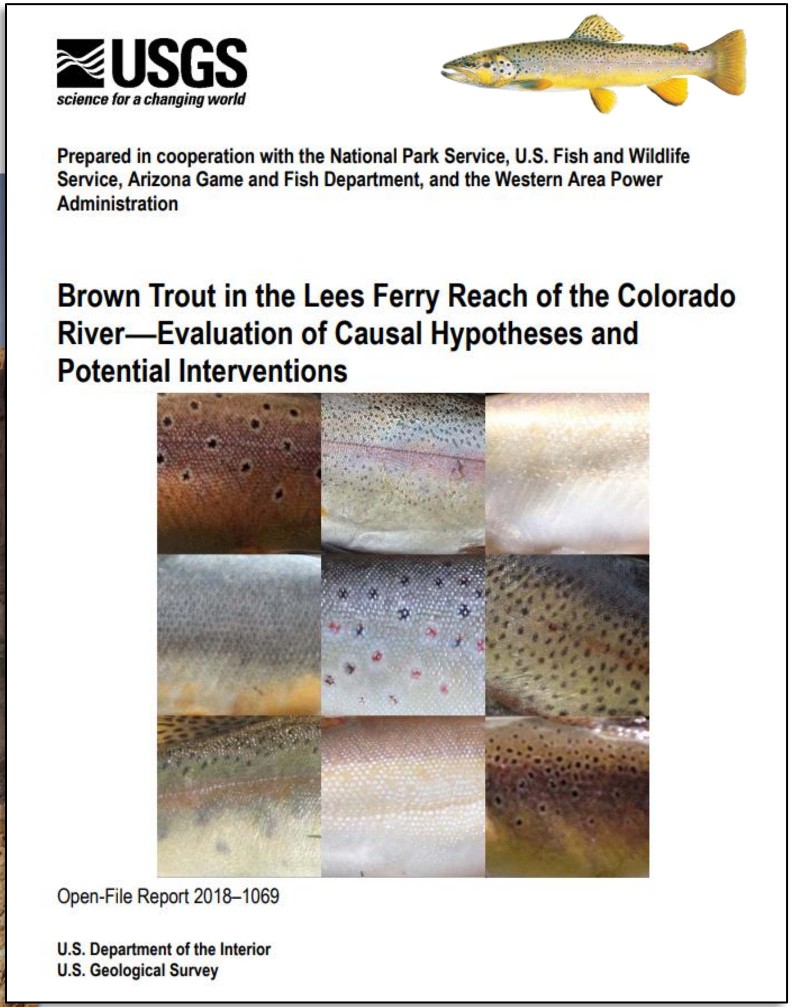
Prepared in cooperation with the Bureau of Reclamation, National Park Service, and Argonne National Laboratory

Decision Analysis to Support Development of the Glen Canyon Dam Long-Term Experimental and Management Plan

Scientific Investigations Report 2015–5176

U.S. Department of the Interior
U.S. Geological Survey



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Prepared in cooperation with the National Park Service, U.S. Fish and Wildlife Service, Arizona Game and Fish Department, and the Western Area Power Administration

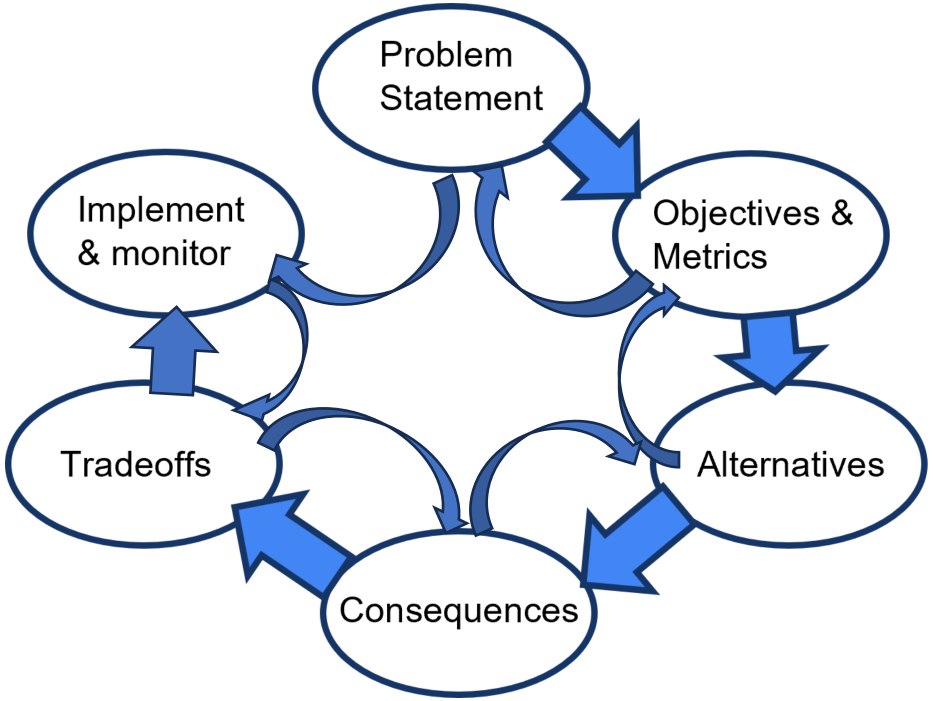
Brown Trout in the Lees Ferry Reach of the Colorado River—Evaluation of Causal Hypotheses and Potential Interventions

Open-File Report 2018–1069

U.S. Department of the Interior
U.S. Geological Survey

Applications for Decision Analysis?

- Planning and Implementation (P&I) Team
  - (Pr, O, A) Making recommendation on flows while considering multiple objectives
    - Multi-criteria decision analysis
  - (C) Predict consequences (quantitatively)
    - Predictive models or formal expert elicitation
    - Incorporate uncertainty directly into analysis
  - (T) Ranking of alternatives based on values and/or risk
- Benefits
  - Identify/prioritize uncertainties for future research & monitoring (value of information)
  - Communication to other stakeholders and tribes
  - Helpful for recurrent and dynamic decisions
    - Enhance learning about critical uncertainties
  - Analysis could be completed over a short period
    - Rapid prototyping approach and iteration



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Applications for Decision Analysis?

- Triannual workplan process
  - (Pr) Portfolio and Information problem
    - Limited resources/budgetary constraints
    - Uncertainty may hinder decision making
  - (O) GCDAMP Goals and Objectives
  - (A) Combinations of project elements
  - (C) Optimization of alternatives
  - (T) Incorporate decision maker's priorities
    - Value of information tools to prioritize research and monitoring
  - Benefits
    - Informed by P&I team decision analysis and VOI
    - Link research to GCAMP goals and decisions
    - Transparency

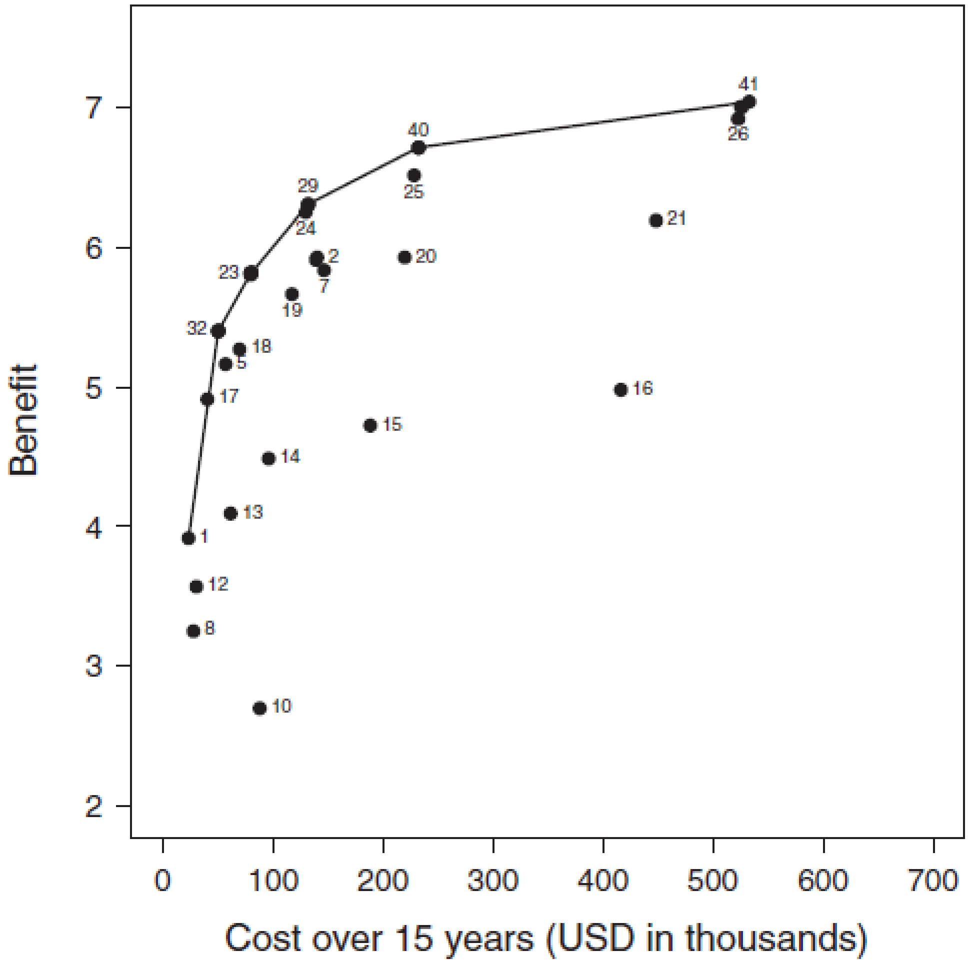

Figure from Lyons, J. E., 2020, *in* Runge et al. (2020), doi:10.1353/book.74951

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Value of Information

For more…..

Healy et al. (2024)

https://doi.org/10.1002/fsh.11174

Questions?

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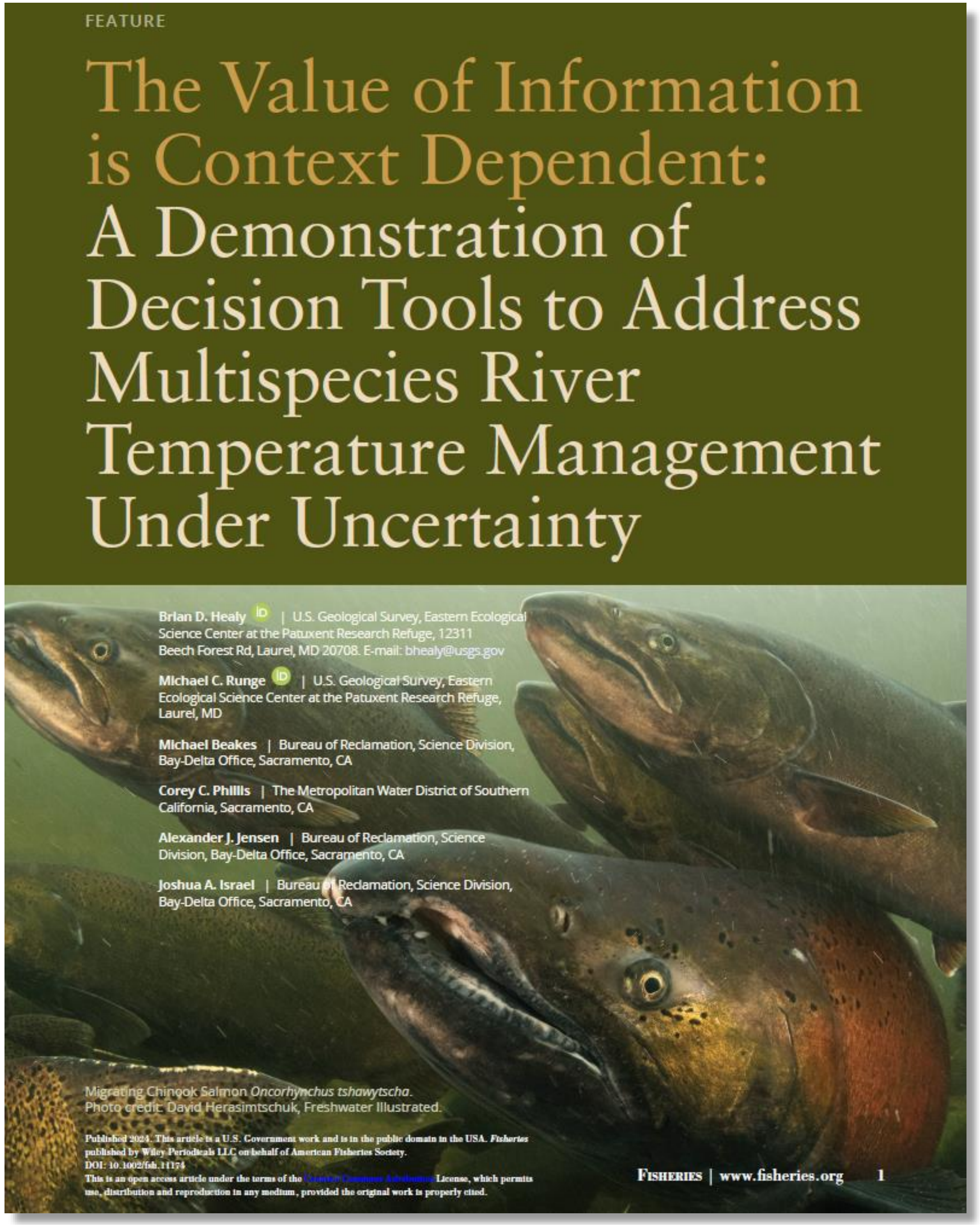
FEATURE

The Value of Information is Context Dependent: A Demonstration of Decision Tools to Address Multispecies River Temperature Management Under Uncertainty

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Migrating Chinook Salmon *Oncorhynchus tshawytscha*.
Photo credit: David Herasimtschuk, Freshwater Illustrated.

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