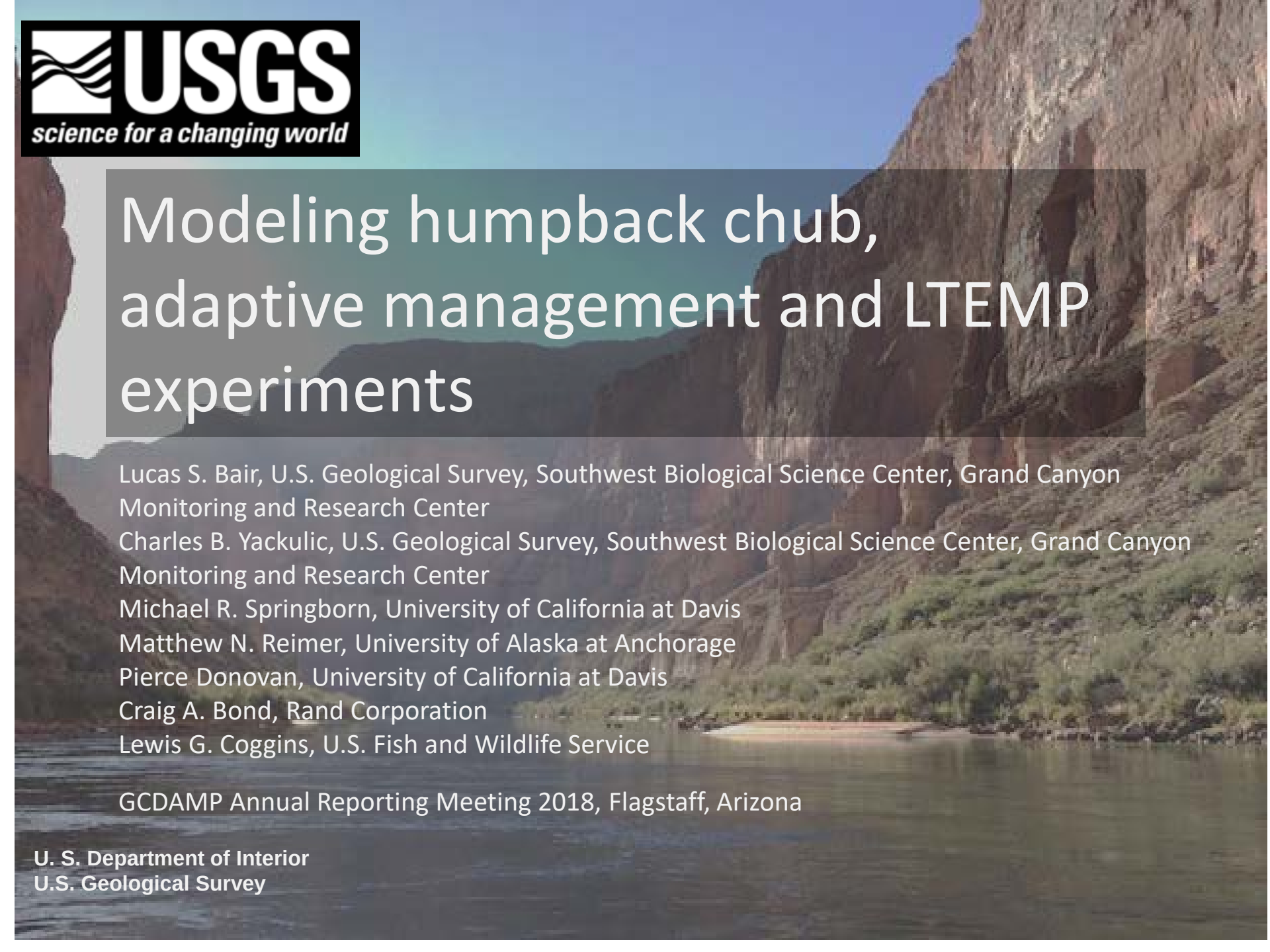


# Modeling humpback chub, adaptive management and LTEMP experiments

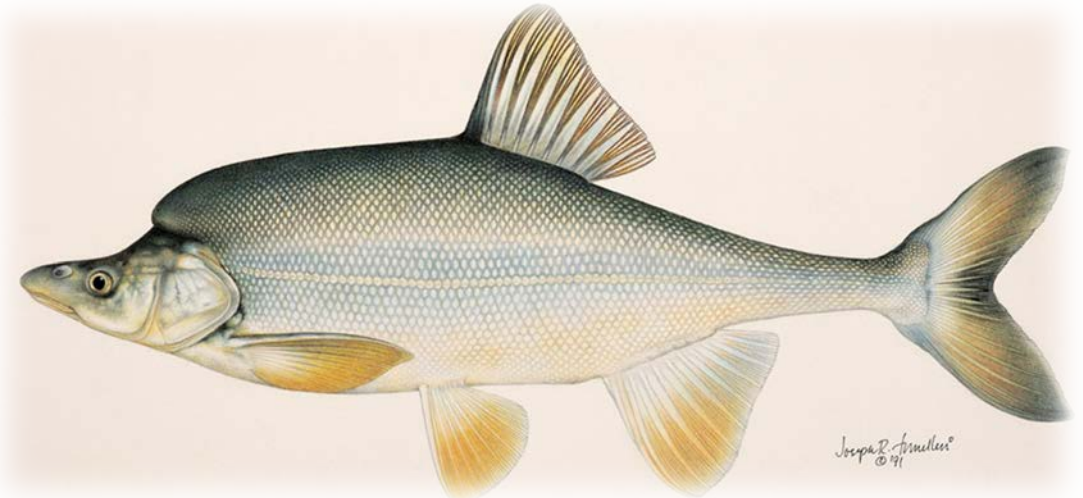
Lucas S. Bair, U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center
Charles B. Yackulic, U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center
Michael R. Springborn, University of California at Davis
Matthew N. Reimer, University of Alaska at Anchorage
Pierce Donovan, University of California at Davis
Craig A. Bond, Rand Corporation
Lewis G. Coggins, U.S. Fish and Wildlife Service

GCDAMP Annual Reporting Meeting 2018, Flagstaff, Arizona

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

# Applied Decision and Scenario Analysis

- Develop a bioeconomic model to identify the cost-effective management strategy for rainbow trout that achieves humpback chub population goals.



http://www.coloradoriverrecovery.org/general-information/the-fish/humpback-chub.html

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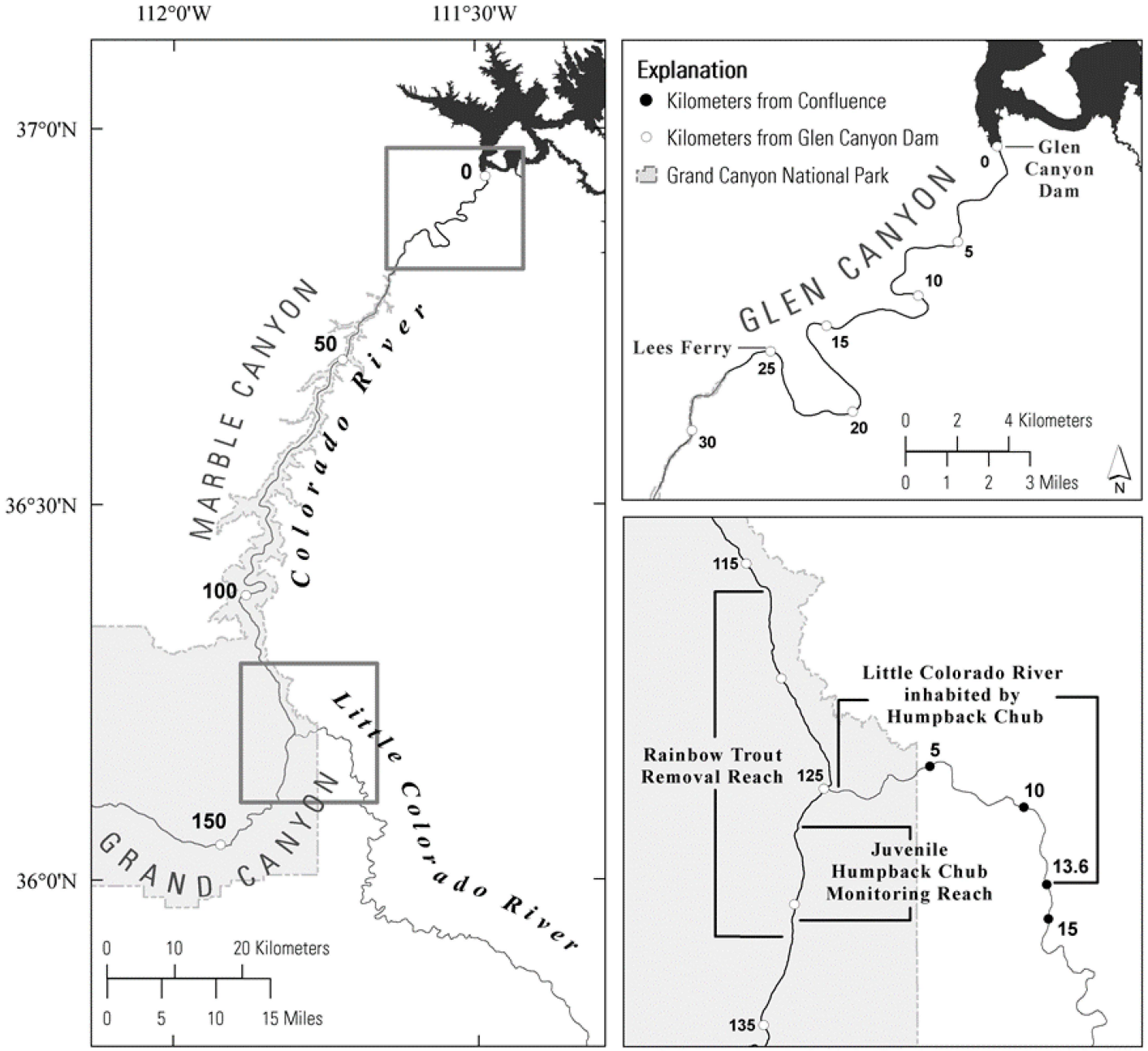
# Cost-effectiveness Analysis

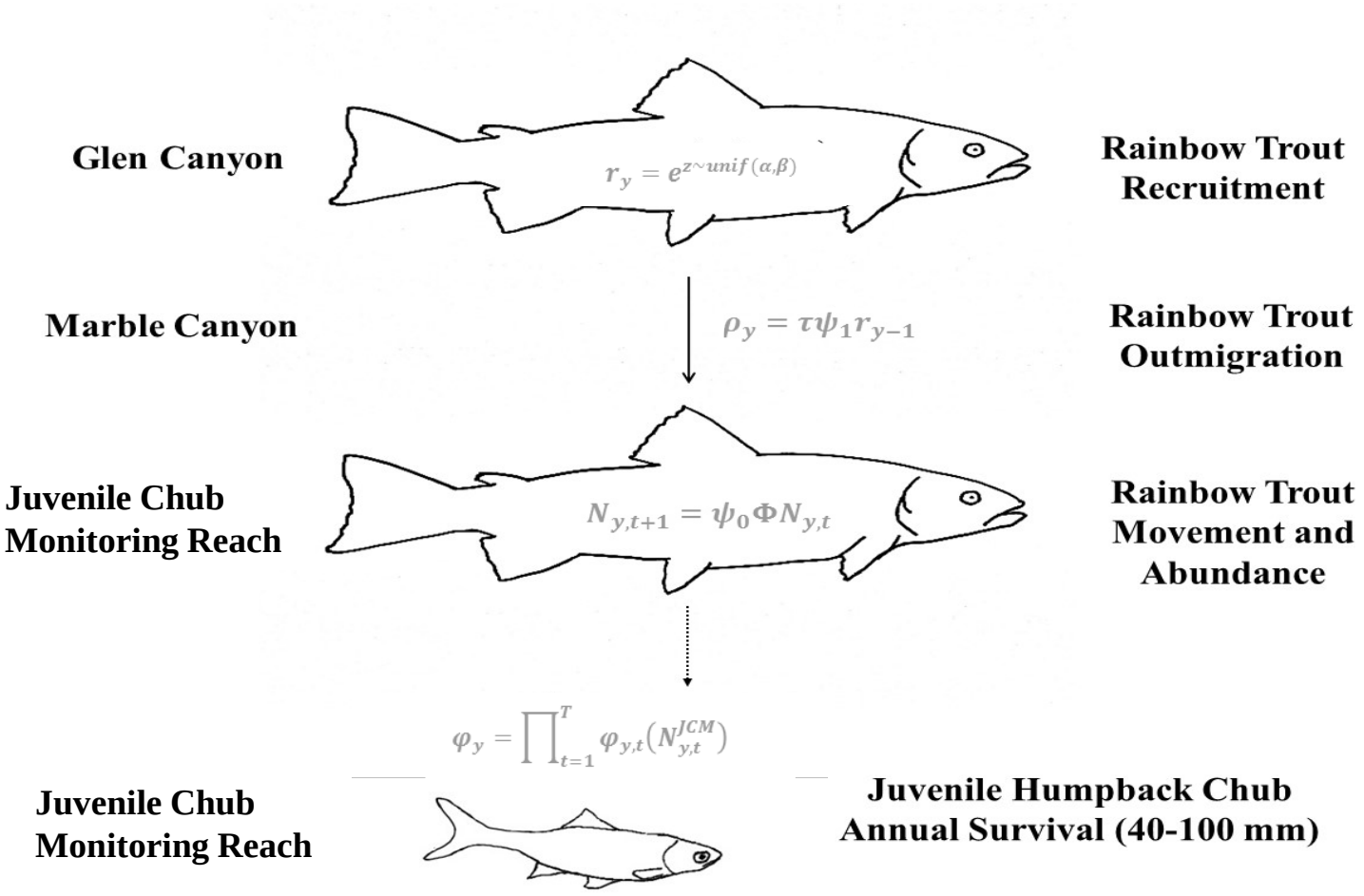
- Comparing the costs of alternative means to achieve goals set through a political or public process (Sagoff 2009)
- Example: Determine an operation at GCD that limits impact to [or improves] hydropower while meeting recovery and long-term sustainability of downstream resources (Reclamation, 1996).

Sagoff, M. 2009. Regulatory review and cost-benefit analysis. Philosophy & Public Policy Quarterly. 29(3/4):21-26.

U.S. Department of the Interior. 1996. Operation of Glen Canyon Dam, Record of Decision. Upper Colorado Region, Salt Lake City, Utah.

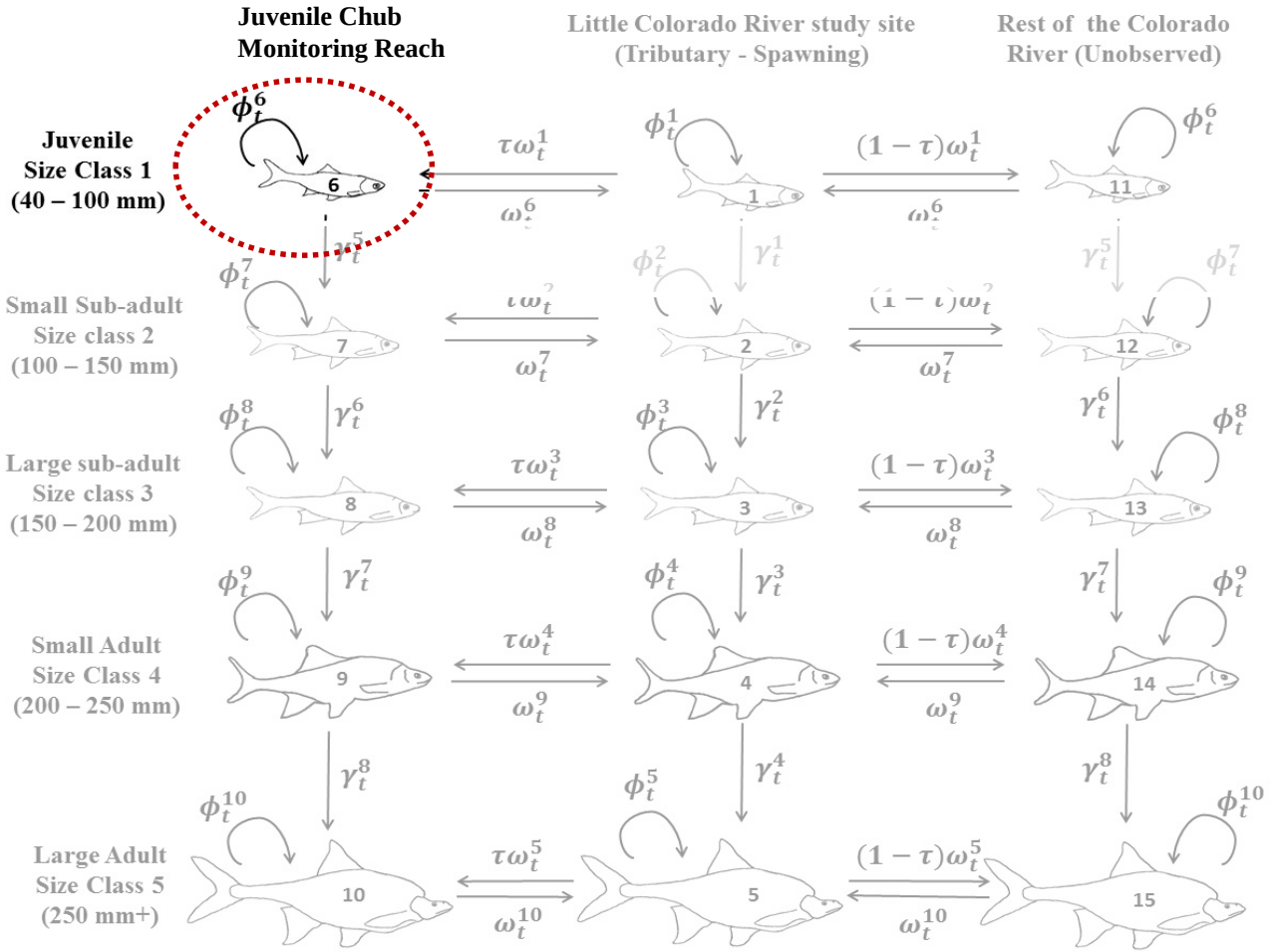

112°0'W
111°30'W
37°0'N
36°30'N
36°0'N
MARBLE CANYON
Colorado River
GRAND CANYON
Little Colorado River
0
50
100
150
0 10 20 Kilometers
0 5 10 15 Miles
Explanation
Kilometers from Confluence
Kilometers from Glen Canyon Dam
Grand Canyon National Park
GLEN CANYON
Glen Canyon Dam
Lees Ferry
0
5
10
15
20
25
30
0 2 4 Kilometers
0 1 2 3 Miles
N
115
Little Colorado River inhabited by Humpback Chub
Rainbow Trout Removal Reach
125
5
10
13.6
15
Juvenile Humpback Chub Monitoring Reach
135

# Bioeconomic Model



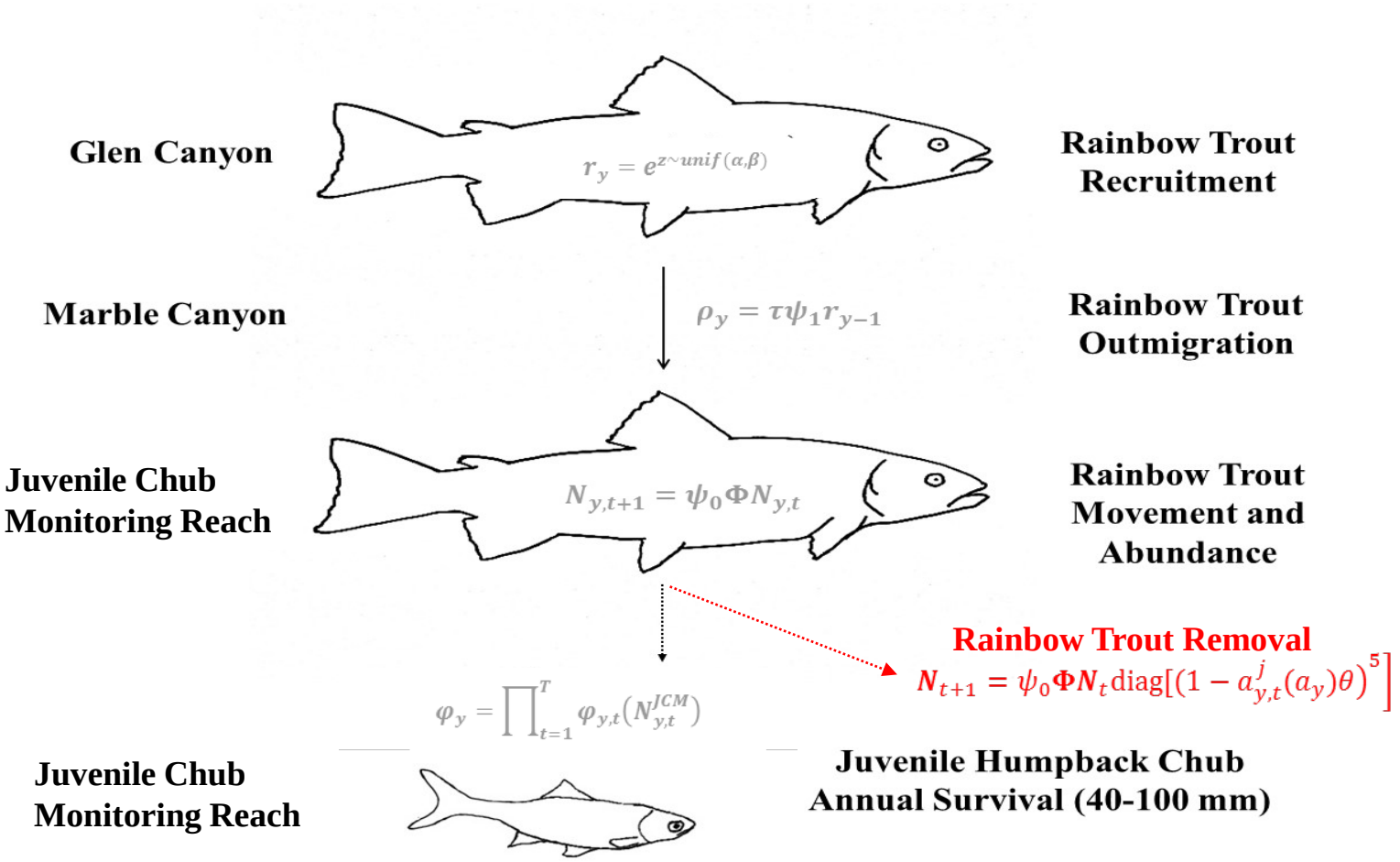

Lucas S. Bair, Charles B. Yackulic, Michael R. Springborn, Matthew N. Reimer, Craig A. Bond, Lewis G. Coggins. 2018. Identifying cost-effective invasive species control to enhance endangered species populations in the Grand Canyon, USA, Biological Conservation, 220, 12-20, https://doi.org/10.1016/j.biocon.2018.01.032

# Humpback Chub (Gila cypha)




Adapted from: Yackulic, C. B., M.D., Yard, J. Korman, and D.R. Van Haverbeke. 2014. A quantitative life history of endangered humpback chub that spawn in the Little Colorado River: variation in movement, growth, and survival. Ecology and Evolution 4(7): 1006-1018.

# Bioeconomic Model

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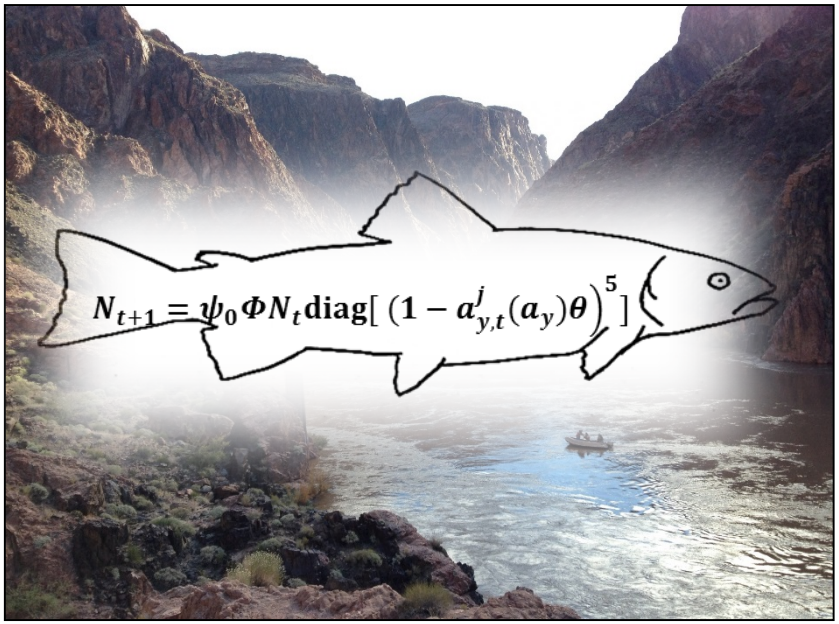
Lucas S. Bair, Charles B. Yackulic, Michael R. Springborn, Matthew N. Reimer, Craig A. Bond, Lewis G. Coggins. 2018. Identifying cost-effective invasive species control to enhance endangered species populations in the Grand Canyon, USA, Biological Conservation, 220, 12-20, https://doi.org/10.1016/j.biocon.2018.01.032

# Management Component

- Mechanical removal
  - Remove rainbow trout in the vicinity of JCM reach
  - Limit of one trip per month and six trips per year
- Minimize costs
  - Number of trips
  - Period of analysis

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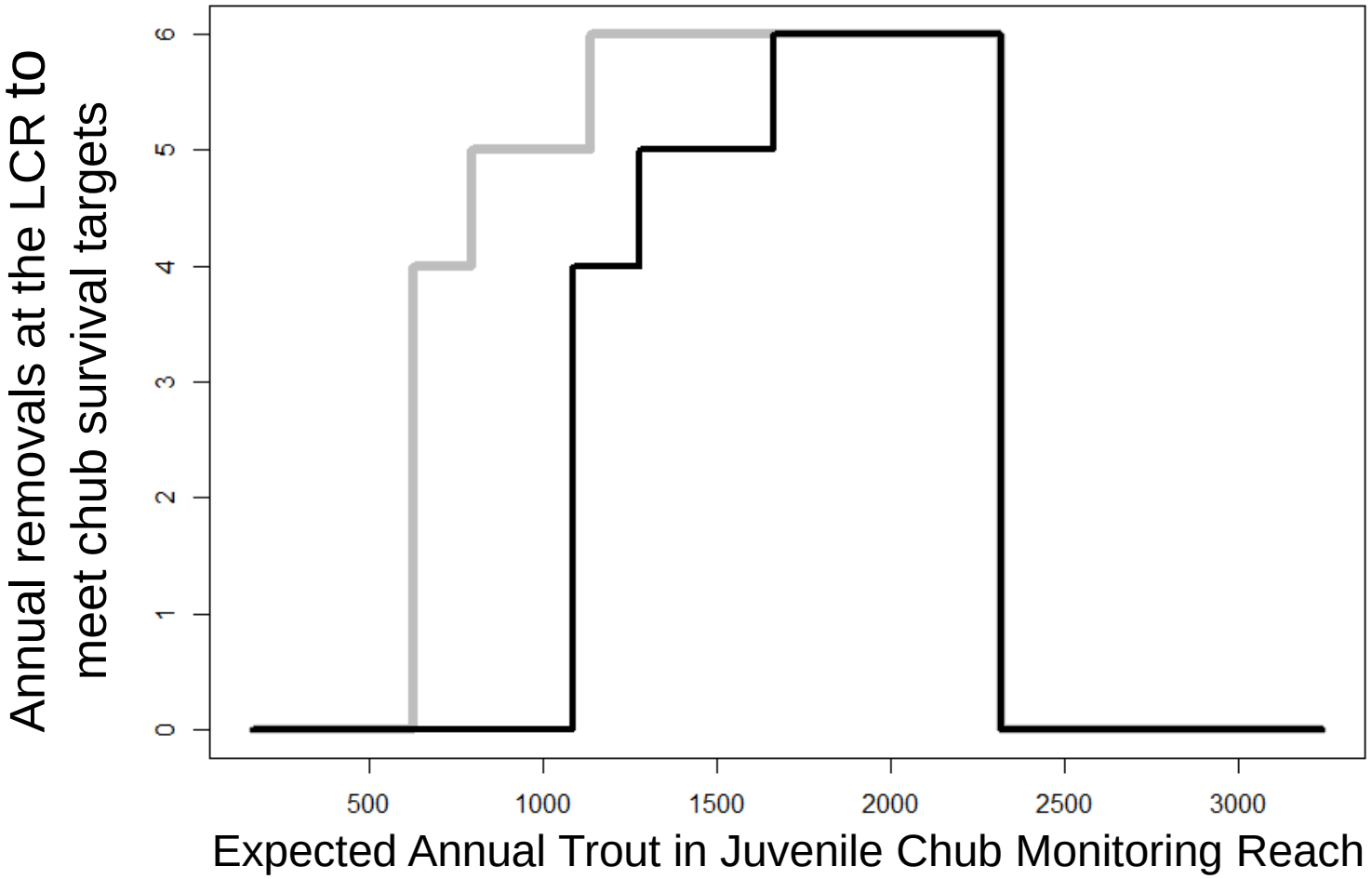
# Bioeconomic Model Results

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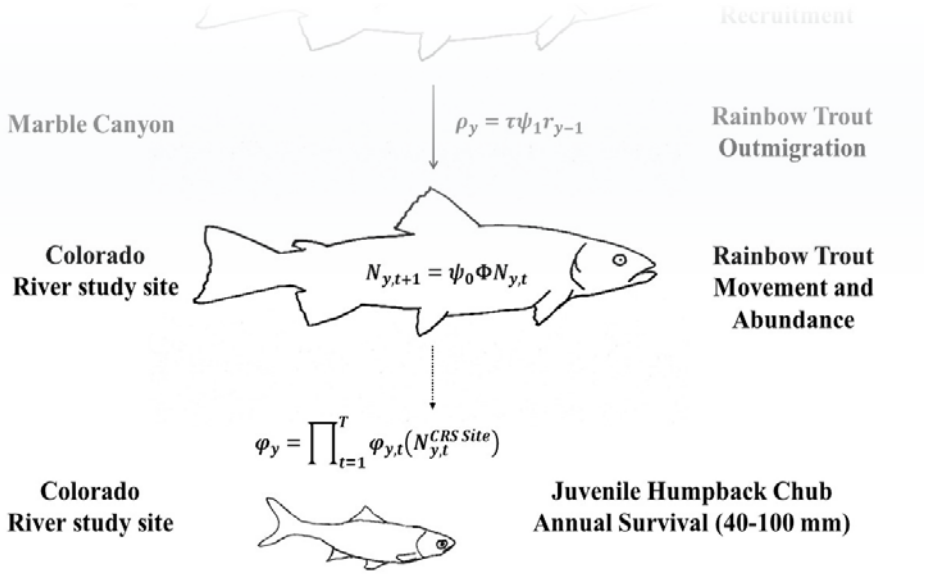
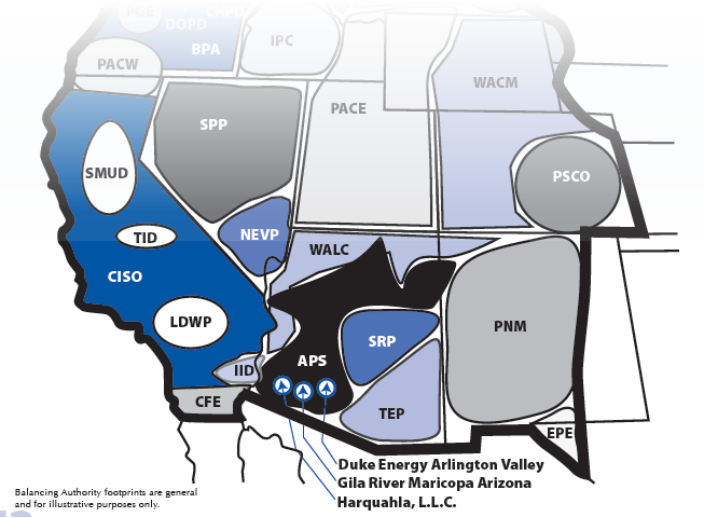
# LTEMP EIS Objectives

- ‘Determine the appropriate experimental framework that allows for a range of programs and actions…keeping with the adaptive management process’



# LTEMP EIS Objectives

- ‘Minimize emissions and costs to the greatest extent possible, consistent with improvement and long-term stability of downstream resources.’

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# GCMRC Research

- Trout management flows
  - Incorporate additional management options and associated costs, such as trout management flows at GCD, into the bioeconomic model
- Humpback chub population parameter uncertainty
  - Identify the importance of parameter uncertainty in the prioritization of monitoring and research

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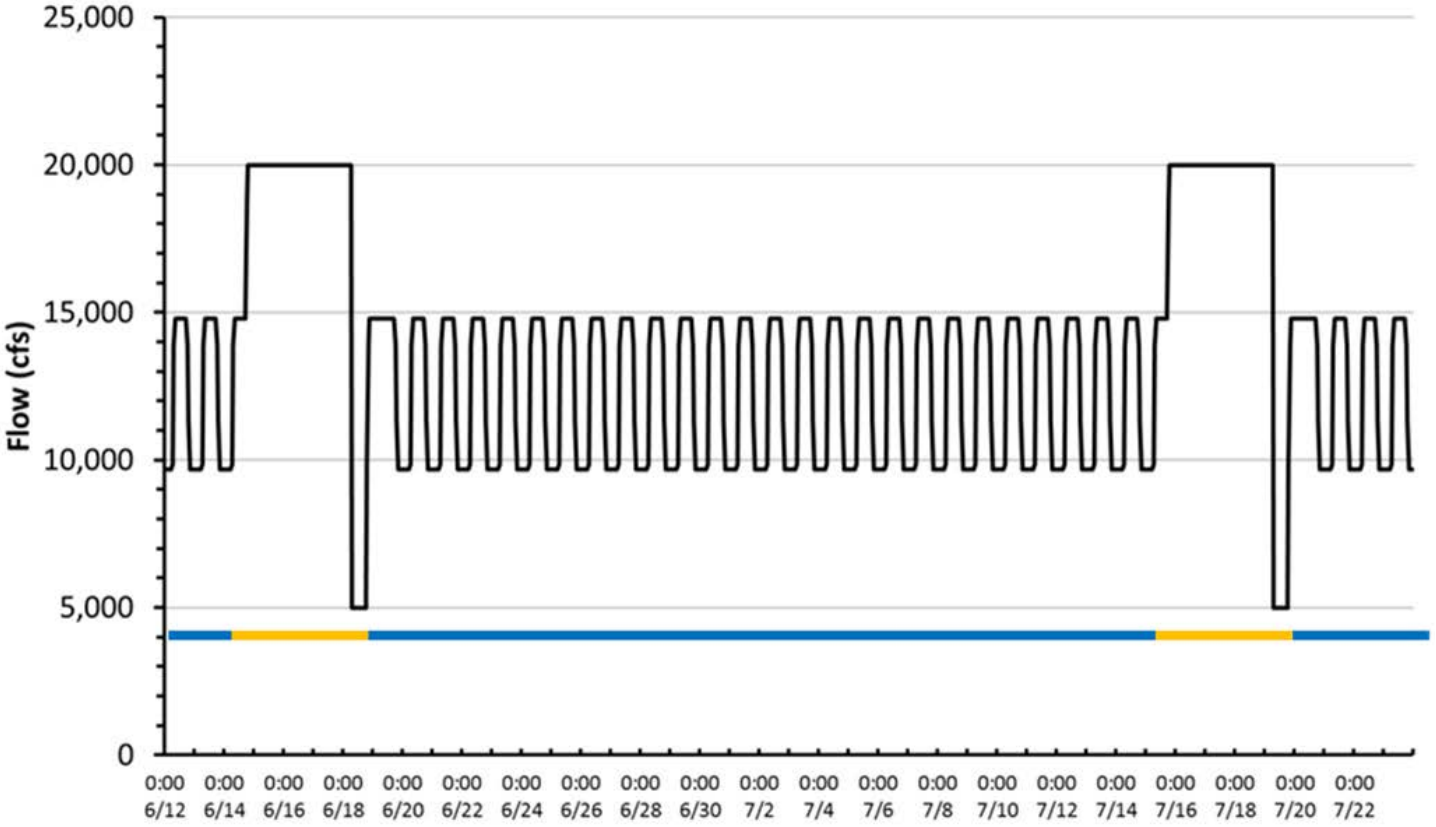
# Trout Management Flows




Example implementation of a two-cycle TMF in June and July with resumption of normal fluctuations between cycles and afterward

*Adapted from: Glen Canyon Dam Long-Term Experimental and Management Plan December 2015 Draft Environmental Impact Statement http://ltempeis.anl.gov/documents/draft-eis/vol1/Chapter_2-Alternatives.pdf*

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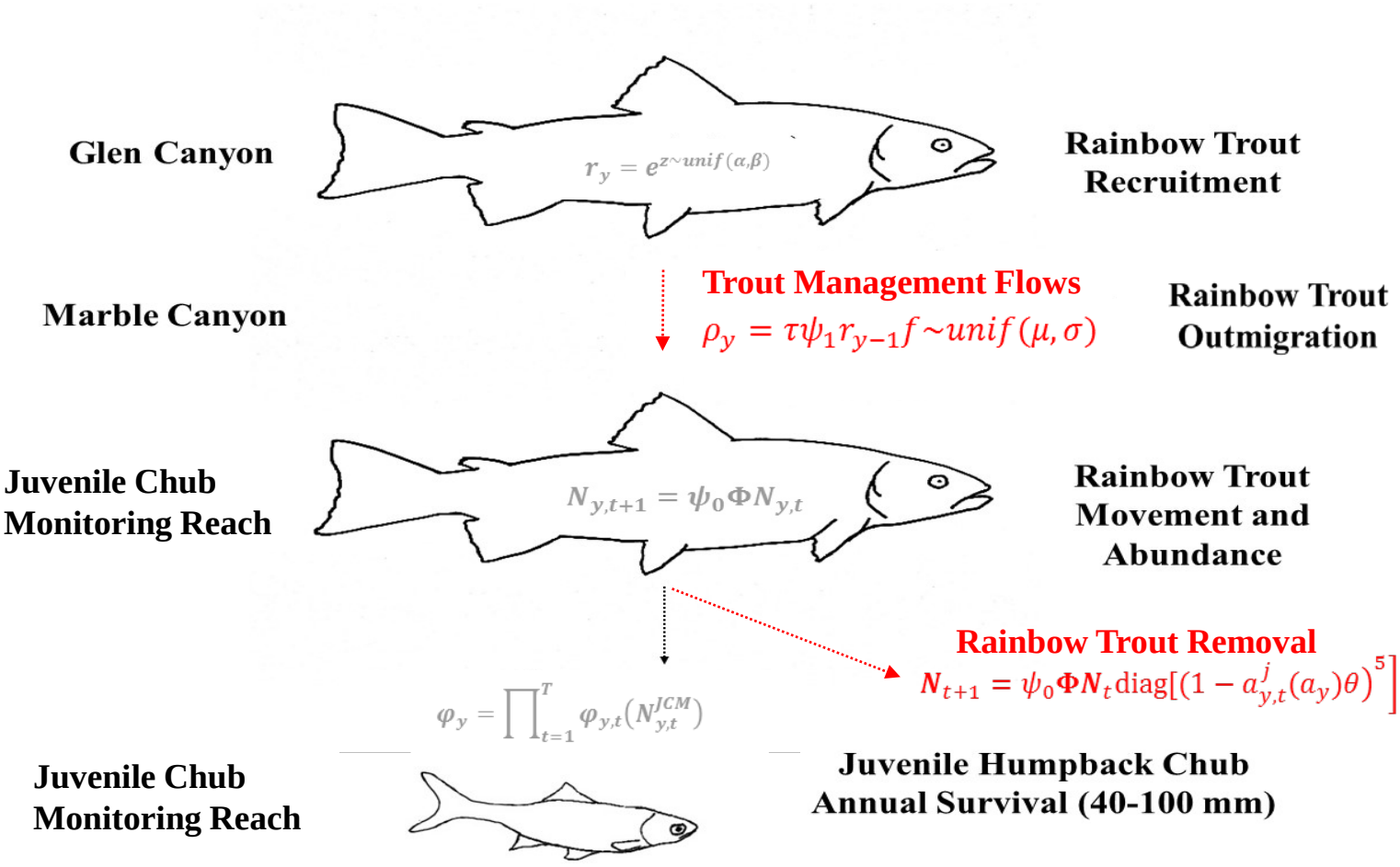
# Bioeconomic Model

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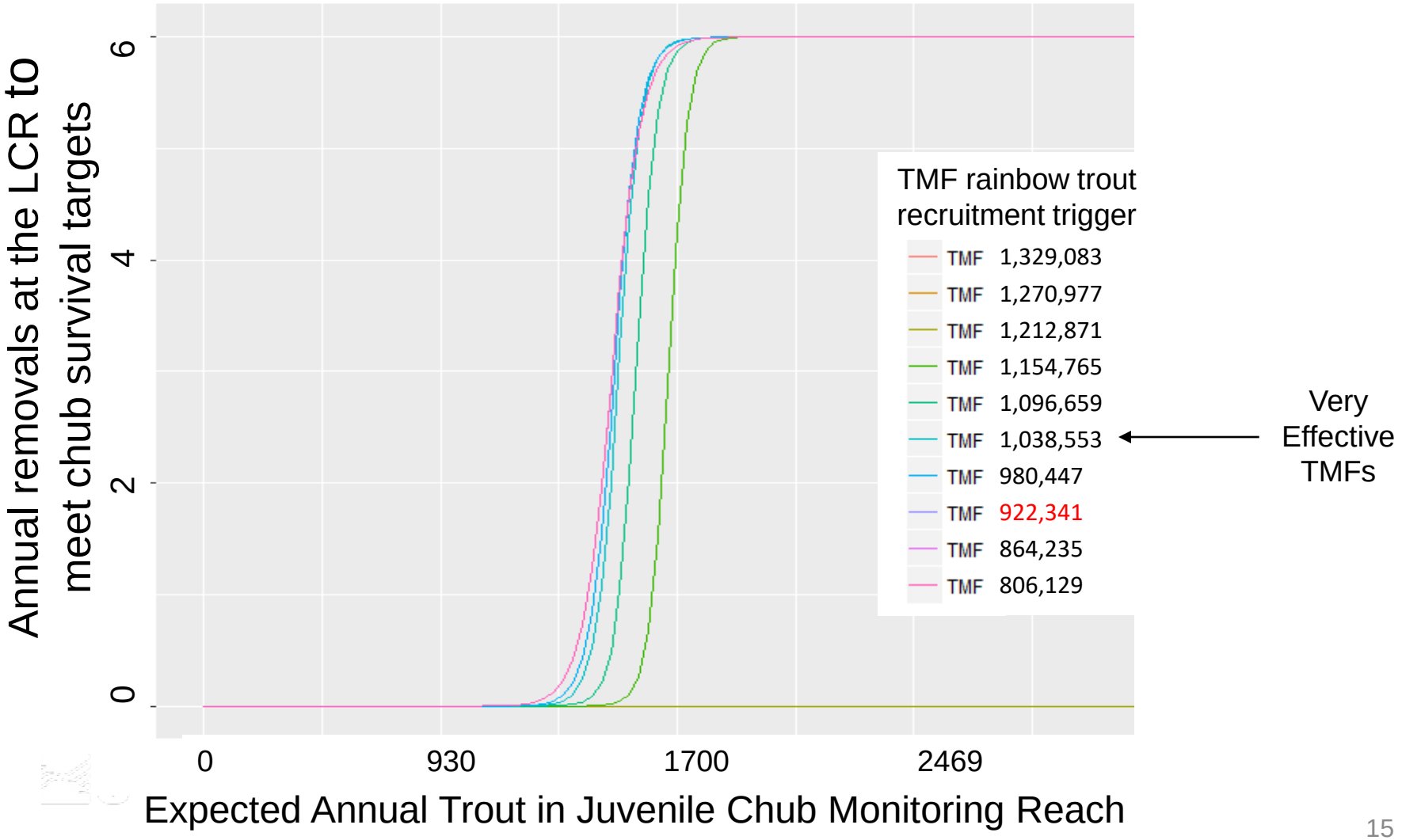
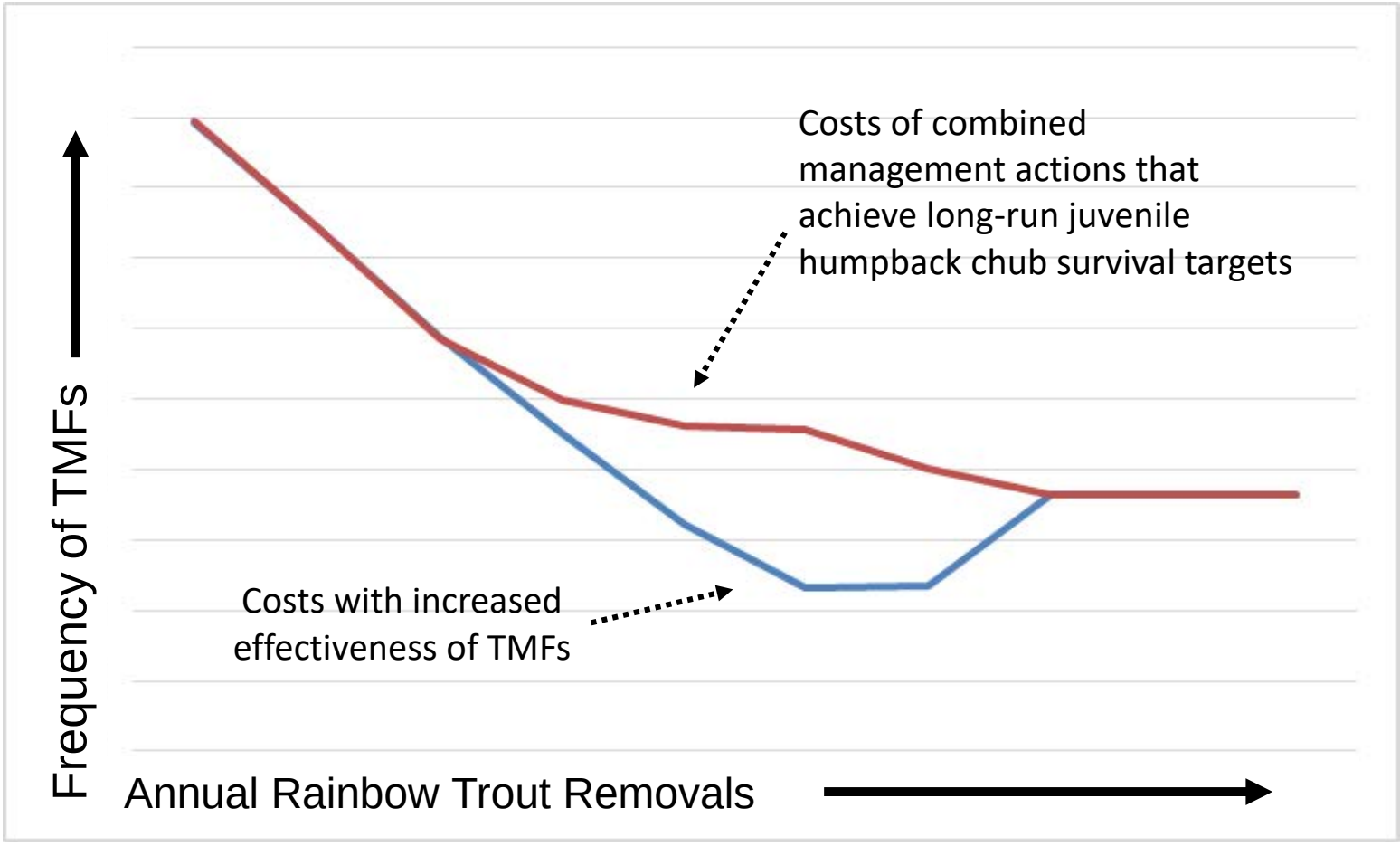
# Optimal Management Strategy




Preliminary data, do not cite

# Optimal Economic Strategy

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# Adaptive Management

- Reducing parameter uncertainty may improve long-run management (i.e., reduce costs) but it incurs short-run costs
- Incorporate active or passive learning into the model as a state variable
- Dynamic programming is a frequent solution but requires that we further simplify the population model

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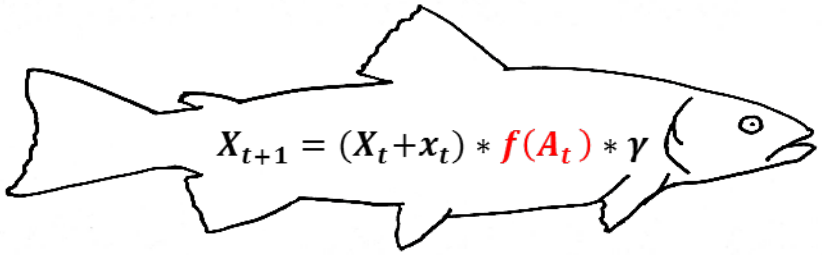
# Bioeconomic Model

**Juvenile Chub Monitoring Reach**



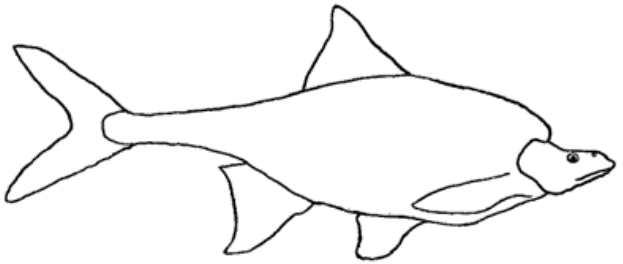
$$X_{t+1} = (X_t + x_t) * f(A_t) * \gamma$$

**Rainbow Trout Population Dynamics**

**Juvenile Humpback Chub Annual Survival (40-100 mm)**

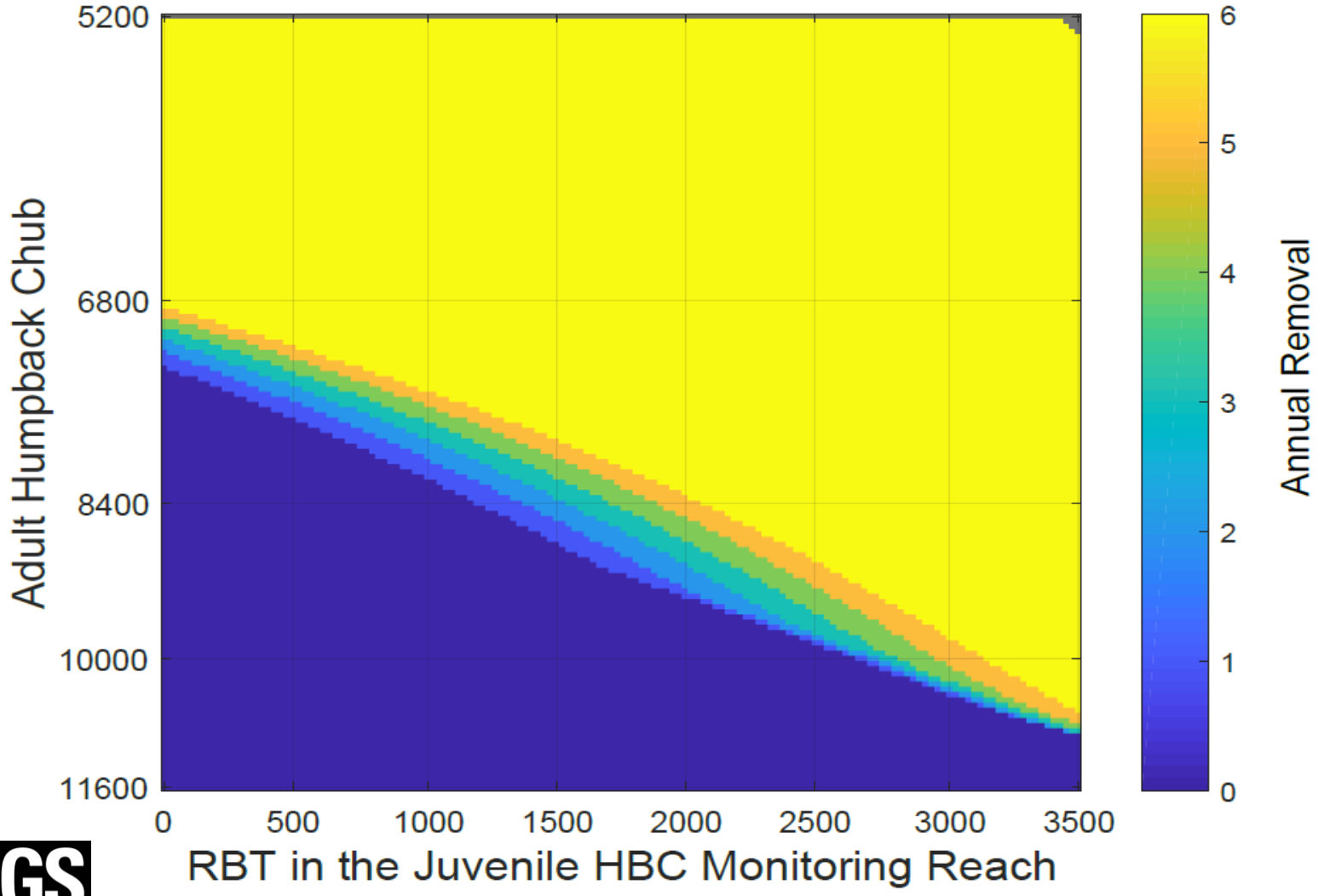
$$\varphi(X_t) = \left(\frac{1}{1 + exp(-(\mu + \lambda * X_t))}\right)$$

**Equivalent Adult Humpback Chub (100 mm+)**



$$Y_{t+1} = Y_t * \eta + y_t * \varphi(X_t)$$

# Dynamic Programming Model

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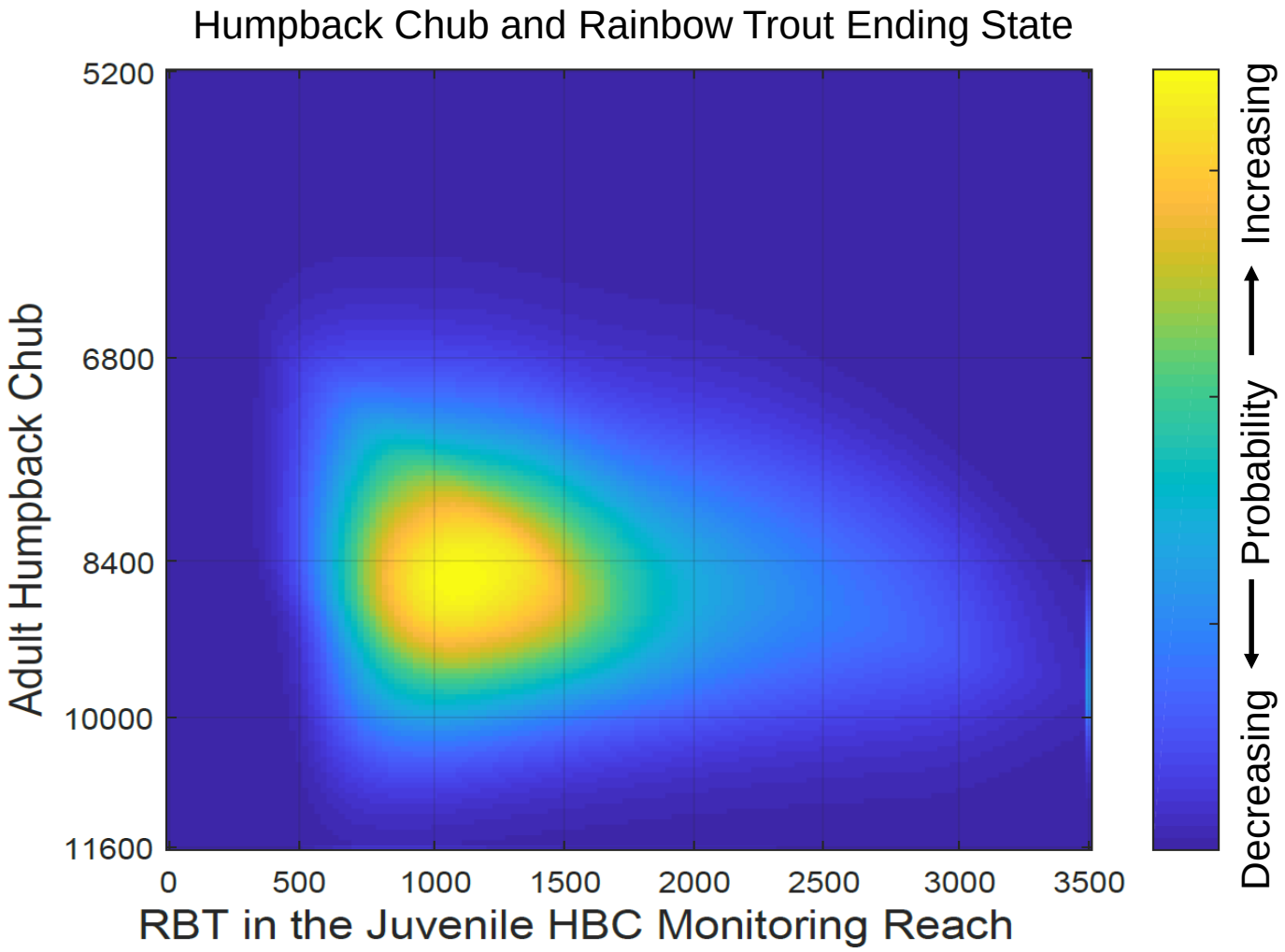
Preliminary data, do not cite

# Dynamic Programming Model



# Adaptive Management

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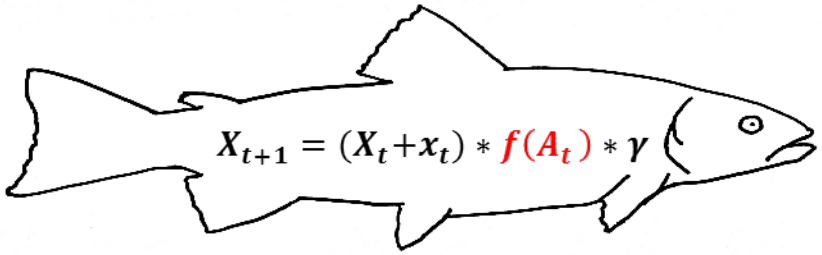


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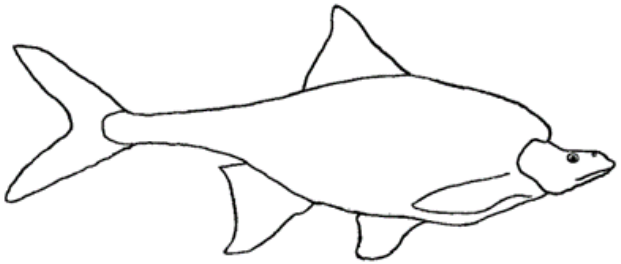
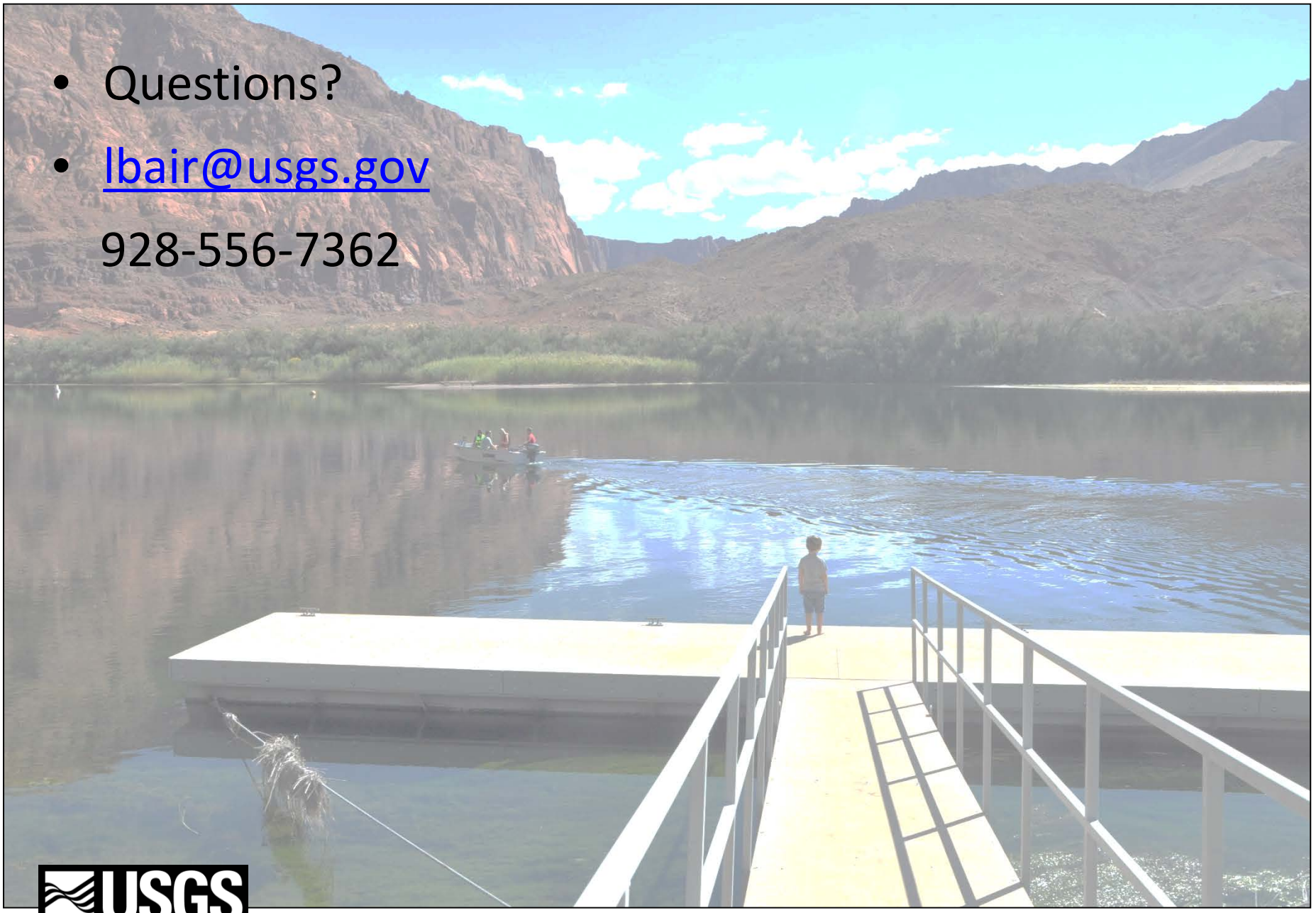


$$Y_{t+1} = Y_t * \eta + y_t * \varphi(X_t)$$


• Questions?
• lbair@usgs.gov
928-556-7362
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