Modelling to support Adaptive Management

Charles B. Yackulic*, Lucas Bair*, Mike Runge, Brad Butterfield, Kimberly Dibble, Paul Grams, Clayton Palmer, Thomas Veselka

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

In an applied setting, where the focus is on recurring decisions,

1. The central role of scientists is prediction

2. Critical uncertainty (uncertainty that matters to the decision maker) is reduced by confronting predictions with data from monitoring (and research).
Expected number of adult brown trout as a function of management alternative and causal hypothesis

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights</td>
<td>0.25</td>
<td>0.07</td>
<td>0.07</td>
<td>0.25</td>
<td>0.07</td>
<td>0.07</td>
<td>0.25</td>
<td></td>
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<tr>
<td><strong>Alternatives</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Status Quo</td>
<td>13,228</td>
<td>11,439</td>
<td>15,476</td>
<td>19,820</td>
<td>12,505</td>
<td>17,995</td>
<td>20,587</td>
<td>16,948</td>
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<tr>
<td>Incentivized Fishing</td>
<td>8,077</td>
<td>5,976</td>
<td>8,311</td>
<td>12,097</td>
<td>6,577</td>
<td>9,185</td>
<td>11,572</td>
<td>9,772</td>
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<tr>
<td>Reduced Fall Flow</td>
<td>7,366</td>
<td>11,439</td>
<td>15,476</td>
<td>6,881</td>
<td>12,505</td>
<td>17,160</td>
<td>9,782</td>
<td>9,629</td>
</tr>
<tr>
<td>Enhanced Spring Flow</td>
<td>6,225</td>
<td>9,723</td>
<td>13,051</td>
<td>5,929</td>
<td>10,875</td>
<td>14,553</td>
<td>8,708</td>
<td>8,299</td>
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<tr>
<td>Trout Mgmt Flows</td>
<td>11,446</td>
<td>9,136</td>
<td>12,112</td>
<td>16,952</td>
<td>10,245</td>
<td>15,204</td>
<td>17,259</td>
<td>14,283</td>
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<tr>
<td>Trout Removal</td>
<td>7,303</td>
<td>4,801</td>
<td>6,393</td>
<td>10,329</td>
<td>5,277</td>
<td>7,560</td>
<td>9,731</td>
<td>8,299</td>
</tr>
<tr>
<td><strong>Best</strong></td>
<td>6,225</td>
<td>4,801</td>
<td>6,393</td>
<td>5,929</td>
<td>5,277</td>
<td>7,560</td>
<td>8,708</td>
<td>6,704</td>
</tr>
</tbody>
</table>
Session Goals

Discuss the role of modeling in an adaptive management program

- Review some of the predictive models developed during LTEMP EIS
- Discuss developments since 2015
- Consider the interplay between monitoring and modeling
LTEMP Modeling Framework (1)
LTEMP EIS (2014): State and Transition Model

- Common vegetation types
- Transitions between states triggered by
  - Plant growth
  - Flow change (e.g. inundation, drying)
- Combinations of 5 1996 LTEMP options
  - Daily fluctuations
  - HFE
  - Equalization
  - Sustained low flows
  - Spill control flood
- Transitions based on studies from within CRe and the broader region

From Ralston and others 2014 USGS OFR 2014-1095
Advances Since 2014

- Annual monitoring program 2014-present
  - >20,000 plots surveyed in systematic way
- New types of data
  - Remotely-sensed vegetation classifications
  - Plant functional traits
  - Greenhouse experiments
  - Biodiversity informatics
- New modeling approaches
  - Niche modeling with continuous flow variables for >70 common species
  - Hierarchical Bayesian modeling that can integrate diverse data and model types
LTEMP Modeling Framework (2)
Broad overview of coupled ltemp models

- Rainbow trout dynamic in Lees Ferry and outmigration driven by flows.
- Movement to LCR and mechanical removal.
- Chub dynamics driven by water temp, rainbow trout, and other drivers.
- Added Brown trout
- Phosphorous as driver of rainbow trout
- Improved understanding of chub dynamics and role of translocations
LTEMP Modeling Framework (3)
LTEMP modelling and recent improvements

- Updates to Temperature models
  - Improved through added complexity (nonlinear, solar insolation, tributaries)
- Updates to Suitability models
  - Switch to thermal degree days fit to basin-wide occurrences
Example of Future Thermal Suitability

Water Temperature Predictions

Native Fish
- Humpback Chub
- Razorback Sucker
- Colorado Pikeminnow

Nonnative Fish
- Channel Catfish
- Smallmouth Bass
- Red Shiner

Dibble and others, 2020
LTEMP Modeling Framework (4)
Sediment model used for LTEMP

Shifting-rating curve sand routing model

- In the LTEMP analyses, metrics were derived for:
  - Sediment resources
  - Archeological and cultural resources
  - Recreation resources
- This is also the model used by Reclamation to plan HFEs

Model covers RM 0 to RM 87 (Lees Ferry to Phantom Ranch)
New sandbar model will soon be available for scenario testing

Model simulations reducing the number of HFEs are larger during HFE protocol.

Over the period of the protocol, sandbars are at least 70% of maximum observed size for 80% of the time.

Fewer HFEs = reduced sandbar size

Without protocol, sandbars are that large only 20% of the time.

preliminary data and results subject to review, do not cite
Glen and Grand Canyon Performance Metrics in the LTEMP EIS

- Glen Canyon Rafting Metric
- Catch Rate Index
- Number of trout >16 inches
- Glen Canyon Inundation Metric
- Camping Area Index
- Navigational Risk Index
- Fluctuation Index
- Time Off River Index
Updated Recreation Metrics

Net Economic Value per Trip ($2015)

Constant Colorado River flow in cubic feet per second

Economic Value per Trip ($2015)

Colorado River Flow in cubic feet per second

Bishop et al. 1987
Meldrum et al. In Prep
Bair et al. 2016

$0  $50  $100  $150  $200  $250
3,000  10,000  25,000  40,000

$636  $560  $1,263  $1,378  $1,118
5,000  10,000  20,000  40,000

Net Economic Value per Trip ($2015)

Bishop et al. 1987
Meldrum et al. In Prep
Bair et al. 2016

$0  $250  $200  $150  $100  $50
3,000  10,000  25,000  40,000
LTEMP Modeling Framework (6)
Three Main Models and Several Supporting Tools Were Used to Support LTEMP Power System Analyses

Colorado River System Simulation (CRSS)
- Simulates Colorado River Basin water management under uncertainty – monthly time step
- Monthly reservoir water releases and storage levels are projected for a large number plausible futures
- Water management (model results) vary by LTEMP EIS Alternative

AURORA
- Estimates hourly Western Interconnection (WI) energy market price trends that are used a primary driver for basin hydropower plant operations
- Projects the expansion of new generating resources for each large CRSP customer
- Customer-level expansion plans vary by Alternative

Generation and Transmission Maximization (GTMax) model
- Patterns hourly water releases and associated electricity generation from basin hydropower plants
- Estimates the firm capacity at Glen Canyon Dam and other basin hydropower resources based on operating criteria and constrains during the peak demand month of the year
- Generation patterns and firm capacity levels vary by Alternative

Model results from AURORA and GTMax were input into a tool that computed power system economic value for capacity and energy under each LTEMP EIS Alternative
GTMax Optimizes SLCA/IP Hydropower Plants Operation (Capacity: 1,820 MW)

Colorado River Storage Projects
- Glen Canyon
- Flaming Gorge
- Blue Mesa
- Morrow Point
- Crystal

Collbran Project
- Upper Molina
- Lower Molina

Rio Grande Project
- Elephant Butte

Seedskaede Project
- Fontenelle

Dolores Project
- McPhee Dam
- Towaoc Canal

Operations
- Plant-level generation
- Ancillary service assignments
- Goals/guidelines

Constraints
- Physical water/power limits
- Environmental/water delivery

- Elephant Butte Serves SRP Loads
- Dolores serves project use

MAP: Locations of storage and operational projects along the Colorado and Rio Grande rivers.
Conclusion

- Substantial improvement in predictive modeling
- Potential to continue to improve and integrate models across resources
- Need to prioritize monitoring, research and modeling that directly and efficiently addresses uncertainties to achieve potential