Knowledge Assessment: Foodweb

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Outline

- Conceptual Diagram
- Lees Ferry
- Grand Canyon
Direct Impact of Dam Itself is Relatively Minor
Glen Canyon Dam has Dramatically Altered the Physical Template

- Temperature regime
- Reservoir carbon and nutrients
- Seasonal/Annual Flow
- Daily flow variation
- Experimental Flood

Fish production

Tributary sediments
Geomorphology
Changes in Physical Template Affect Habitat and Food Resources of Fishes

- Fish production
- Invertebrate production
  - Algae production
  - Reservoir carbon and nutrients
  - Seasonal annual flow
  - Daily flow variation
- Tributary flood carbon
- Tributary sediments
- Geomorphology
- Glen Canyon Dam
- Temperature regime
- Riparian plant carbon
- Reservoir carbon and nutrients
- Experimental flood
Requires Interdisciplinary Studies

Diagram showing relationships between various ecosystem components:
- Fish production
- Invertebrate Production
- Algae production
- Tributary Flood carbon
- Tributary sediments
- Geomorphology
- Experimental Flood
- Daily flow variation
- Seasonal Annual Flow
- Reservoir carbon and nutrients
- Temperature regime
- Riparian plant carbon
- Glen Canyon Dam

Links between these components illustrate the complexity and interdependence of ecosystem processes.
Overarching Questions

1. To what degree are fishes food limited? Where does the food base come from?

2. How do patterns of carbon flow through the food web affect fishes?

3. How do dam operations affect all of these things?

These questions require an ecosystem approach based upon flows of energy.
To address questions we have...

1. Measured inputs, stocks, outputs, and transport of primary production and terrestrial inputs in the Colorado River.


3. Identified trophic linkages to estimate what resources support higher trophic levels.

4. Quantified organic matter flow in the Colorado River food web from basal resources to fishes.
Why an ecosystem approach based on energy flows?

1. Animal population dynamics depends on ecosystem properties such as
   a. Amount, source and quality of food
   b. Physical template (flow, turbidity, temperature)
   c. Competition and predation with other animals
   d. Interaction of the above

2. Energy flow allows a common currency from everything from organic matter inputs to fish production

Units:
grams organic matter meter$^2$ year

Energy is more or less equivalent to organic matter
Two Different Rivers

Carothers & Brown, 1991

KEY
- Sediment Input
- Clear Water
- Low Sediment Content
- Medium Sediment Content
- Highest Sediment Content

Increasing Turbidity With Downstream Flow

Glen Canyon Dam

Kanab Creek

Peria River

Colorado River

Little Colorado River

Rainbow Trout
Increased trout production despite reduced total prey production following the 2008 controlled flood

Cross and others 2011 Ecological Applications
Trout Production

(g AFDM m$^{-2}$ y$^{-1}$)

- 06-07
- 07-08
- 08-09

The graph shows the trout production from 2006 to 2009, with the highest production in 2008-2009.
Filamentous algae
The 2008 artificial flood stimulated production of key invertebrate taxa

Overall ~60% Decrease

- ~80% Decrease
- ~70% Decrease
- ~30% Increase
- ~200% Increase
Quantitative Food Webs
Reduced flows to invertebrates
Increased flows to trout
Midge and black fly drift increased after the flood.
Trout Consumption Determined by Availability = Drift
Midge Drift Increased Following 1996 HFE

Shannon and others, unpublished data
Trout production tracks Chlorophyll Production

![Graph showing annual chlorophyll production from 1998 to 2010. The graph indicates a decrease in chlorophyll production from 2002 onwards, with a significant drop in 2008. The 2008 value is noted as biased due to no sampling from March 12 to June 14 (missed spring bloom).]
We Now Have A Working Lees Ferry Dissolved Oxygen Model—3 Years Worth of Daily GPP Estimates Coming Soon!!

Estimates are comparable to previous approaches

Similar metabolism estimates under steady flow conditions

Simulation of unsteady flow matters

Different metabolism estimates under unsteady flow conditions

Rob Payn et al., *in prep*
Two Different Rivers
Tributary-Derived Organic Matter Dominates the Input Budget
Turbidity Limits Primary Production in Grand Canyon

Bob Hall, unpublished data
Primary Production—Diamond Creek

- Gross Primary Production (g O₂/m²/d)
- Discharge (m³/s)
- Log₁₀ Turbidity (ntu)

But effects of operational changes can be persistent

Effects of turbidity are transitory...
Why Does Production Approach Zero When Discharge Fluctuates in November?
High discharge, but not necessarily fluctuations, decreases total algae production in Grand Canyon.

Table 2. Areal estimates were calculated for the geomorphic reaches and include: total wetted area (TWA), mean channel depth (Z), light attenuation coefficient (Ko), photosynthetically available area (PAA) and areal percent (PAA%). Zenith angles used for estimating Ko (mid-day estimate) varied seasonally from 60.4° to 13.5°. Maximum photosynthetic photon flux density (PFD) for summer and winter seasons range between 2020-1980, and 1200-1150 μmol quanta m⁻² s⁻¹ respectively. Compensation point used (30 μmol quanta m⁻² s⁻¹) was specific to C. glomerata.

<table>
<thead>
<tr>
<th>Flow Discharge 142 m³ s⁻¹</th>
<th>Flow Discharge 568 m³ s⁻¹</th>
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<tr>
<td><strong>CHANNEL</strong></td>
<td><strong>SUMMER</strong></td>
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<td>TWA</td>
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<td>Lower Granite Gorge</td>
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<td><strong>TOTAL</strong></td>
<td>2,746</td>
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Yard (2003)
Invertebrates consume a high proportion of diatoms relative to availability

Wellard-Kelley and others, *in prep*
Provisional Data – Subject to Change
Invertebrate Diets Track Diatom Availability

% of diet that is diatoms

% of epilithon that is diatoms

\[ r = 0.63 \]

% of seston that is diatoms

Wellard-Kelley and others, \textit{in prep}

Provisional Data – Subject to Change
Invertebrate Production Decreases Downstream
Most Invertebrate Production is on Cobble
Invertebrate production is highest on cobble because there is more food there

Kennedy, unpublished data

Provisional Data – Subject to Change
Fish Production +/- Doesn’t Decrease Downstream

Provisional Data – Subject to Change
Downstream fish assemblage is making more complete use of the limited prey base.
High interaction strengths for some inverts suggest fish may be suppressing production.
Rainbow Trout and Humpback Chub have High Dietary Overlap
Relevant Strategic Science Questions:

5. What are the important pathways, and the rate of flux among them, that link lower trophic levels with fish and how will they link to dam operations?

- **Part I**
  - Any pathway involving midges or black flies
  - Direct consumption of algae and detritus might also be important

- **Part II**
  - HFEs stimulate important pathways in Lees Ferry
    - May have also occurred downstream but ecological buffering masked this
  - High discharge during winter appears to reduce algal pathways
  - Low production of prey items in variial zone
6. Are trends in the abundance of fish populations, or indicators from fish such as growth, condition, and body composition (for example, lipids), correlated with patterns in invertebrate flux?

- Definitely true in Lees Ferry
- Some evidence downstream
  - High overlap of invertebrate production and fish demand
  - Annual variation in sucker condition correlated with invertebrate biomass (Paukert 2005)
Relevant Strategic Science Questions:

5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?

- HFES stimulate invertebrate flux in Lees Ferry (and possibly downstream)
- Turbidity depresses algal production and probably invertebrate flux
- High discharge during winter months may depress invertebrate flux
Relevant Strategic Science Questions:

5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?

- Temperature has a huge effect on algae and invertebrate flux
Warming Increases Growth/Production of Algae and Invertebrates

Kennedy and others, unpublished data
Invertebrate assemblage composition

- Pre-dam (<1963)
- Pre-thermal restoration (1965-1978)
- Post-flow Restoration (1994 to present)

Locations:
- Downstream from Flaming Gorge Dam
- Green River
- Whirlpool Canyon
- Yampa River
- RM 60, Little Colorado River
- RM 225, Diamond Creek
- Canyon of Lodore

Abundance Based:
- Blue Chips
- Penny Stocks

Mark Vinson, unpublished data
Temporal Scales of Flow Regime

Temporal Variation in Hydrology

Spatial Variation in Production

Meters

Kilometers

Canyon-wide

Varial Zone

Daily

Monthly

Seasonal

Annual

HFEs??

????

Temporal Variation in Hydrology
Ecologically Important Processes Could Occur During Low Flows
Add ecological buffering capacity to Lees Ferry