Interactions between sediment transport and ecosystem dynamics on large systems

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Basin provides water for

- 27 million people
- >1 million ha in irrigation
- 12 billion kW-hr in electricity
Transitions in the allocation and use of water

agriculture ➔ municipal

snow making

rafting, kayaking
Endangered species

Protected under the Endangered Species Act (ESA), 1973

• Section 4 establishes critical habitat as a regulatory link between habitat protection and recovery goals, requiring the identification and protection of all lands, water and air necessary to recover endangered species.
Endangered because of...

1. Predation by non-native fish

2. Barriers to migration

3. Loss or alteration of habitats...
...changes in hydrology and sediment transport capacity due to construction of reservoirs and water diversions...

peak flows: ~ 30-40% lower now than before 1950
Established in 1988

- A partnership of public and private organizations working to recover the endangered species while allowing continued water development

- Annual expenditures ~ $10 million/yr

- Endangered species will be considered recovered when there are self-sustaining populations of each fish species and when there is natural habitat to support them
Habitats: Areas used for spawning, nursery, feeding and rearing
• Biologists know rare fish are spawning

• They know approx. when the fish spawn ($T \approx 18-20^\circ C$)

• Do not know where the fish are spawning

also...

• Larval fish drift downstream, then move upstream as they mature and grow in size (5-7 yr)

• Most adults are found upstream in gravel-bed reaches
Rationale behind our research

- Habitats used by adult fish for spawning, feeding, etc. appear to be widely distributed... no specific locations are known to be more important than others.

Study area encompasses 250 km of the Colorado River in western Colorado and eastern Utah.
Research Objectives:

• Provide data on thresholds and durations of discharges that perform **important geomorphic functions**, such as

  - maintaining spawning habitat
  - maintaining channel complexity
  - limiting the growth of non-native vegetation (tamarisk)

• Work with biologists to integrate this information with findings from biological studies to refine flow recommendations.
Study area:
11 geomorphic reaches
Total length ~ 250 km

• X-sect meas. every 1.6 km
• GPS meas. every 0.8 km
• 78 samples of the bed surface
• 27 samples of the subsurface
Results

0.002

0.001

0.0003

downstream
Gravel transport thresholds

Shields parameter:

$$\theta = \frac{\tau}{(\rho_s - \rho)gD} = \frac{HS}{(s-1)D}$$

Formulate values of $\theta$ for each of the 150 measured sections
Sediment transport thresholds

**Incipient motion:** Sporadic movement of small numbers of particles.

\[ \tau^* \approx 0.03 \]

**Significant motion:** Near-continuous motion of most particles on the bed.

\[ \tau^* \approx 0.045 - 0.055 \]

**Suspension:** Particles are not often in contact with the bed.

\[ U_* > w_s \]

important for sand sizes
bankfull $\theta$ is $\sim$1.6 times the threshold $\theta$
Depths req’d to reach these thresholds:

\[ H = \frac{\theta 1.65 D}{S} \]

Calculate corresponding discharge (useful for reservoir operations):

\[ Q = W \frac{H^{5/3} S^{1/2}}{n} \]

where

- \( W \) is channel width
- \( H \) is depth
- \( S \) is slope
- \( n \) is a roughness coefficient, obtained by calibrating 1-d hydrodynamic model
Gunnison River (major tributary)

significant motion

incipient motion
Good News! Specific values of Q should produce roughly the same transport intensity on a widespread basis.
How are these results incorporated into reservoir operations?

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<thead>
<tr>
<th>Flow Targets for Forecasted Inflows</th>
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<td>Duration (days)</td>
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Peak Flow Target at Whitewater
Most recent estimate of the population of CPM

~ 900 fish total

Good news, but habitat requirements are still largely unknown

Osmundson, 2009
Most of the “functions” of rivers are related in one way or another to sediment transport.

“The continuity of the river is not disturbed by anthropogenic activities and allows undisturbed migration of aquatic organisms and sediment transport” (WFD, p.40)

• It is difficult and time consuming to measure sediment transport, but...

• It is not so difficult to measure the river properties that reflect sediment transport...

• The ensemble trends in width, depth slope, grain size can be used to assess the mass balance (continuity) of sediment and take appropriate management actions