Discussion of the Bug Flows Synthesis and Review & Opportunities for Spring and Summer Flow Experiments

Ted Kennedy

1-US Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, Flagstaff, AZ
Why Bug Flows?

~80% of aquatic insects have cementing egg laying strategies that are vulnerable to artificial tides.

Year-round hydropower fluctuations do not support natural processes essential to diverse and resilient invertebrate assemblages.

Figure 2: Larval and egg mass photos of *Baetis* spp. (Ephemeroptera) (A, E), *Brachycentrus occidentalis* (Trichoptera) (B, F), Chironomidae (Diptera) (C, G), and *Hydropsyche occidentalis* (Trichoptera) (D, H). Photo credits: Morgan Ford (A), Greg Wada (B, C, D), and Matt Schröer (E, F, G).

Photos of aquatic insects (top) and eggs cemented on various substrates (bottom).

From Miller and others 2020, Freshwater Science
Why Bug Flows?

- Daily hydropower fluctuations create “tides”
- Insects lay eggs at water line at dusk
- When tide drops, eggs dry, die

Bug Flows seeks to mitigate this

From Kennedy and others 2016, Bioscience
What is a Bug Flow?

- Give bugs the weekends off
- Weekend stable low flows from May-August
  - 34-36 days/years
  - Tested 2018-2020
- Eggs laid on weekends never dry

Unpublished data, subject to change, do not cite.

https://waterdata.usgs.gov/az/nwis/uv?site_no=09380000
Goals of Bug Flows

- **Proximate Objective**
  - Improve egg laying conditions for aquatic insects

- **Ultimate Objective**
  - “Improve food base productivity and abundance or diversity of mayflies, stoneflies, and caddisflies”

Table 4, LTEMP EIS

From Attachment B: Table 4, p. B-14, LTEMP-Record of Decision
Bug Flows-Key Findings

- Enhanced natural processes and improved food base
  - More egg laying substrates
  - More insect emergence
  - More caddisflies (but not midges)
  - More GPP
    - Condition of native fish & humpback chub positively related to GPP
- Enhanced rainbow trout fishery
  - Higher catch rates

Unpublished data, subject to change, do not cite.
Science Advisor Review
Timeline

- October 12-GCMRC submits Bug Flow report
- October 28-Bug Flow workshop #1
- November 4-Bug Flow workshop #2
- January 4-Science Advisor review received
- January 11-ARM presentation w/ 2021 light trap data
- January 13-TWG meeting (today)
Take Homes from Science Advisors

- **Bug Flows was successful**
  - Ruhi: “...Bug Flows were successful, overall, in enhancing natural processes...”
  - Downes: “Experiment successfully met proximate and ultimate objectives”
  - Kroll: “...high likelihood the experiment has worked...”
  - Colvin: “The Bug Flows are meeting primary and proximate objectives and the science being conducted is cutting edge.”
Take Homes from Science Advisors

- Report should include more details
  - More statistics
  - Include summary table
  - Better link to hypotheses and objectives
  - Separate direct vs. indirect effects

- Summary table of research question, hypotheses, and expectations is needed

- A table summarizing all data available would be useful. Adding basic metadata would be valuable for the reader and could spur research synthesis

- Present hypotheses and their associated predictions in the introduction, unexpected results should not be considered “failures”
## Take Homes from Science Advisors

- **More analyses and modeling would be informative**
  - Dynamic ecosystem models
  - Species-level analysis of abundance
  - Trait analysis

- **System of dynamics models could show connections between experiments**
  - Michael Colvin

- **Invertebrate trait analysis and species-level response due to traits**
  - Albert Ruhi

- **Species-level abundance data and differences in egg-laying strategies would bring clarity to the effects of Bug Flows**
  - Barbara Downes

- **Species-level sampling would provide more data and confirmation on experiment results**
  - Benthic sampling once per year at low flows is recommended
  - Stephanie Kroll
Take Homes from Science Advisors

- **Thoughts about Future Experiments**
  - Add months
  - Shifting months could be informative
  - Opportunity cost of changing design

1. Changing the experimental design potentially creates opportunity costs. By altering the way the hypotheses are tested, you run the danger of further complicating a scientific story that is complex and not yet fully understood. Indeed, an opportunity cost has arguably already

- Longer block of steady flows (i.e., more months within a year) could help reduce the uncertainty regarding the role of flows

- Mar/April-July experiments might show which times of year are most beneficial to bugs
Take Homes from Science Advisors

- Quantifying environmental benefits
- Compensating hydropower

Obviously, the power company can measure its losses very precisely and in dollars; how is this weighed up against the environmental benefits of experiments like Bug Flows? A difficulty is that many environmental benefits do not lend themselves to measurement using dollars. Sure, we can price up the cost of running an experiment like Bug Flows, or we can calculate how much people might pay for the privilege of angling for Rainbow Trout in an improved fishery, but the value of gaining knowledge that prevents ecosystem collapse or extinctions is arguably priceless.

An agreed method for balancing costs—however they are measured—gives everyone clarity, sets some ground rules, acknowledges that repairing decades of environmental damage costs money and can be expensive, and potentially gives everyone an incentive to work for the best solution overall. Such a formula might explore options for the power company to seek tax write-offs or to gain environmental credits that deliver benefits back to the company.
### Opportunities for Spring and Summer Flow Experiments

<table>
<thead>
<tr>
<th>GCD Experimental Flow</th>
<th>Duration</th>
<th>Implementation Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring HFE $\Delta$</td>
<td>up to 96 hours</td>
<td>March – April</td>
</tr>
<tr>
<td>Proactive Spring HFE $\Diamond$</td>
<td>24 hours**</td>
<td>April – June</td>
</tr>
<tr>
<td>Trout Management Flows</td>
<td>up to 3 cycles/month for 4 months</td>
<td>May – August</td>
</tr>
<tr>
<td>Macroinvertebrate Flows</td>
<td>target 2-3 replicates</td>
<td>May – August</td>
</tr>
<tr>
<td>Fall HFE</td>
<td>up to 96 hours</td>
<td>October - November</td>
</tr>
<tr>
<td>Extended Duration Fall HFE</td>
<td>97- 192* or 97-250 hours***</td>
<td>October - November</td>
</tr>
</tbody>
</table>

$\Delta$ no Spring HFE in same WY as extended duration Fall HFE
$\Diamond$ no proactive Spring HFE in same WY as sediment-driven Spring HFE

---

**Not yet tested:**
- 1996, 2008
- 1996, 2008

---

* First test not to exceed 192 hours
** First test 24 hours
*** After first test, up to 250 hours

---

Preliminary data, do not cite.