Flow Regulation: environmental effects in long term

Diego García de Jalón
Flow Regulation: Environmental Effects in the medium and long term

1. Types of Flow Regulation and Hydrological Impacts
2. Changes in Sediment budget
3. Bio-Geomorphologic responses
4. Biological responses
5. Regulation extension & Resilience
6. Restoration & Hysteresis
1. Types of Regulation and regulation impacts

- **Reservoir uses types:**
  - Irrigation
  - Domestic & industrial use
  - Hydropower

- **Regulation intensity:**
  - Regulation Index: *Annual flow/reservoir capacity*
    - > 1: Hiper-reservoirs

- **Hydrological impacts**
1. Regulation intensity: impacts

IMPACTS: according to how much instream flows were outside of the 'Range of Natural Variability' along the year.
Short-term flow fluctuations
**WATER for IRRIGATION**

**Río Jucar (Tous)**

**Caudales medios (m³/s)**

- 1912-1930: 55.3
- 1945-1981: 41.5
- 1997-2014: 12.8

Flow reduction
WATER for IRRIGATION

Río Genil (Iznajar)

‘Mediterranean’ regime toward a ‘Monzonic’ regime

Maximum monthly flows in summer

Caudales medios (m3/s)

<table>
<thead>
<tr>
<th></th>
<th>1942-61</th>
<th>1967-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.3</td>
<td>13.9</td>
<td></td>
</tr>
</tbody>
</table>

Flow reduction:
Water-supply Reservoirs: Changes in flow regime in a bypass reaches, and downstream urban sewage treatment plants.

**Bypass:**

River Jarama (Algete)

- 1939-70
- 1971-94

\[ Q_{ma} = 12.3 \, \text{m}^3/\text{s} \]

\[ Q_{ma} = 6.4 \, \text{m}^3/\text{s} \]

**Downstream cities**

río Jarama (Puente Largo)

- 1968-72
- 1973-2009

\[ \text{Mean daily Flow (m}^3/\text{s)} \]
2. Changes in Sediment budget

Rivers have lost their sediments

• the reservoirs act as huge sediment traps,

• But also:
  • abandoned high lands have reduced the sediments sources,
  • gravel mining takes away the sediment left.
Effects of Sediments Retention by dams

- Rivers below dams have lost almost all of their sediment yield.
- After the dam is closed, released ‘hungry waters’ drag sediments from the bottom in a size-selective process.

**Stages of Substrate Evolution:**

- Along years, there is a *wave* of sediment deficit that moves downstream along the river, changing its substrate traits: caliber increase and armoring.
- Later, substrate comes to an *equilibrium* between the regulated flow regime and sediment input by tributaries.
- The effects on the biota vary in space and time according to these stages of substrate change.
Rivers have lost their dynamism

• Reservoirs laminate larger floods
• Bankfull discharges become very rare,
• Riparian vegetation overgrowths invading channel river margins,
• Humans fix rivers by constructing levees and longitudinal dykes.
Channel Geo-morphic changes

- Alteration of erosion and sedimentation processes:
  - Reduction
  - Unbalance
- Incision
- Decrease in channel size
- Channel Stabilization

The river Bonsai concept
The evolution of river Ruecas (Guadiana basin)
Impacts of modified channel morphology on salmonid habitat
Trinity River, California
images courtesy S. McBain

Salmonid fry require clean exposed cobble gravel channel margins with low water velocity

Riparian berms

Sand deposits along channel margins

Fry rearing habitat provided only during low flow periods
4. Biological responses
Efectos en las Comunidades Acuáticas

• Fragmentación de poblaciones

• Interferencia del embalse como habitat nuevo

• Modificación del hábitat fluvial:
  – Perdida de su torrencialidad
  – Condiciones mas predecibles

• Muchas especies autóctonas están poco adaptadas, pero no todas!

• Invasión de especies introducidas leniticas
Especies introducidas

- carpin
- Black-bass
- gambusia
- carpa
- gobio
- lucio
- Pez-gato
- Pez-sol
Flow Regulation Extension to the entire Hydrographic Network has Synergistic effects that increase its Impacts.
• Ecological **Resilience** is the property of an ecological system that determines the persistence of *relationships within the system* (Holling, 1973)

• Dams are physical **barriers** that prevent the migration of fishes, and the arrival of seeds, plant sprouts upstream, as well as the drift of benthic invertebrates.

• Numerous dams in the same river and its tributaries **fragment** the river ecosystem and disconnect its communities, making it difficult to recover from disturbances.
5. Restoration & Hysteresis

- **Hysteresis** is the time-based dependence of a system's output on present and past inputs. Represents an asymmetrical process.

- Regulated flows often promote **vegetation encroachment** in river channel.

- Once **mature forest** stands are established, it is anchored by sediment accumulation and development of a dense root system.

- Setting E-flows, neither Flushing Flows is often not enough.

- Alternatives?
5. Restoration & Hysteresis

Effects of Riparian Vegetation Hysteresis

b & c: niche construction sequence induced by pioneer plants (encroachment)

d: succession into a mature riparian forest

Corenblit et al. 2009
The river Bonsai concept: Mediterranean regulated rivers

- Rivers have lost sediments
- Rivers have lost their dynamism
- Rivers have been fragmented and lost their longitudinal connectivity
- Rivers are narrower and disconnected laterally
- The rivers are immobilized by an overgrown riparian vegetation
- Rivers have reduced their native biodiversity
- Rivers have been invaded by introduced species

CONCLUSIONS
Conclusion: We must adopt a new E-Flows template.

**Potential E-Flows actions**

1. Hydrologic regime
2. Sediment Transport regime
3. Woody Debris dynamics

**Complementary measures**

- Removing mature Riparian Forest
- Eliminating/Reducing Barriers
- Direct Morphological reconstruction

**MORPHOLOGICAL CHANGE**

**HABITAT IMPROVEMENT**

**ECOLOGICAL RESPONSE**

**CONCLUSIONS**
Thank you for your attention.