Jun 24th, 8:50 AM - 9:35 AM

Plenary Speaker: Conciliating fish ecology and river fragmentation in South American large rivers: Are fish passages appropriate tools?

Claudio Baigún

*Technological Institute of Chascomus, Brazil*

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Conciliating fish ecology and river fragmentation in South American large rivers: Are fish passages appropriate tools?

Claudio R. M. Baigún

INTECH- CONICET-UNSAM, Argentina
ACKNOWLEDGMENTS

• Herman Wanningen
• Pao Fernández
• KerryBrink
• The aim of this presentation is to review and discuss some of the main characteristics related to dams development and fish passes challenges in main South American basis
SOUTH AMERICA IS THE MOST FLUVIAL CONTINENT!!

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Figure 5.1 Map showing South America’s major river basins

1. Amazon
2. Río de la Plata (Parana-Uruguay)
3. Orinoco
4. São Francisco
5. Magdalena

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Dissolved Organic Carbon

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Numbers of fish species described in the studied regions of South America.
South American fish

• All Iteroparous
• Almost all potadromous
• Life cycles well adapted to cope with high hydrological variability
• Migratory species comprise between 20-45% of fish fauna most of them exhibiting a periodic strategy: free spawning, high fecundity, strong river pulses-recruitment relationships
• Migrations of different types and length

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Spawning in main channels

Eggs and larvae drift

Reservoir

Larvae/juvenile growth in floodplains

Preadult recruitment

Thermal adult migrations

Spawning adult migrations

Dispersion adult migrations

Trophic adult migrations

Dam
Fish composition in Neotropical rivers

- CHARACIFORMS: 46%
- Siluriforms: 39%
- Others: 15%

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Prochilodus lineatus

65 cm

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Aquatic Plants → Herviborous Omnivorous → Carnivorous I level → Carnivorous II level → Zooplankton → Phytoplankton

Herviborous Omnivorous → Periphyton

Aquatic Plants

Herviborous Omnivorous

Benthos

DETRITUS
Piaractus mesopotamicus

70 cm

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Brycon orbygnianus

65 cm

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Pseudoplatystoma coruscans

170 cm

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Pseudoplatystoma fasciatum

150 cm

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Paulicea lutkeni

90 cm

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Leporinus obtusidens

70 cm

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Figura 1. Áreas de criação, alimentação e desova de dourada e de piramutaba no eixo Solimões-Amazonas (Barthem & Goulding, 1997).
• Migratory movements are complex and they comprise not only reproductive migrations but also thermal, trophic and dispersive movements

• Same species in different basins can exhibit different bionomic adaptations according to flow regime
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### Overview large dams per continent

*(UNEP, 2001)*

<table>
<thead>
<tr>
<th></th>
<th>World (incl. China)</th>
<th>Europe</th>
<th>Asia</th>
<th>North and Central America</th>
<th>South America</th>
<th>Africa</th>
<th>Australia-Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of large dams</td>
<td>47655(^a)</td>
<td>5480</td>
<td>5480</td>
<td>8010</td>
<td>979</td>
<td>1269</td>
<td>577</td>
</tr>
<tr>
<td>Average height (m)</td>
<td>31(^b)</td>
<td>33</td>
<td>33</td>
<td>28</td>
<td>37</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Average reservoir area (km(^2))</td>
<td>23(^b)</td>
<td>7</td>
<td>44</td>
<td>13</td>
<td>30</td>
<td>43</td>
<td>17</td>
</tr>
<tr>
<td>Avg. reservoir capacity (million m(^3))</td>
<td>269(^b)</td>
<td>70</td>
<td>268</td>
<td>998</td>
<td>1011</td>
<td>883</td>
<td>205</td>
</tr>
</tbody>
</table>

\(^a\) The primary source of data is ICOLD World Register of Dams (1998, 2000) and estimates by the World Commission of Dams (WCD, 2001).

\(^b\) The ICOLD 1998 database was used to calculate the average dam height, reservoir capacity and surface area by region.
Basin status

Nilsson et al 2005
Figure 5.1 Map showing South America’s major river basins.
Cuenca del Plata

Obras

- 60 m de altura
- 50 MW

- 56 en operación
- 8 en construcción
- 23 proyectos

Datos ICOLD 2002

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PLANALTO (UPLAND)

PLANÍCIE (LOWLAND)

Prof. C.A. Mendes – IPH/UFRGS / WWF Brasil
UHEs
SIGEL/ANEEL

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PCHs
SIGEL/ANEEL

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• New dams will represent an additional 2.5% of energy at national scale
• Recreational fisheries represent the second income resource in the Pantanal: 22,000 employments mobilizing 67,000,000 U$D per year
• Artisanal fisheries encompass almost 10,000 families mobilizing 35,000,000 U$D
Amazon basin

- Constructed: 7%
- In operation: 18%
- Planned: 75%

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Inventoried dams

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There are currently 48 dams greater than 2 MW capacity in the Andean Amazon, but plans for an additional 151 such dams over the next 20 years. 80 of new dams Fifty-three would be 100 MW or greater.
Planificadas: Con estudios de prefectibilidad realizados
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<table>
<thead>
<tr>
<th>Countries</th>
<th>Add Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Status</td>
<td>Add Filter</td>
</tr>
<tr>
<td>Basins</td>
<td>Add Filter</td>
</tr>
<tr>
<td>Capacity / MW</td>
<td>Add Filter</td>
</tr>
<tr>
<td>500 To 1,000 MW</td>
<td></td>
</tr>
<tr>
<td>Flooded Area / Km²</td>
<td>Add Filter</td>
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<tr>
<td>Companies Involved</td>
<td>Add Filter</td>
</tr>
<tr>
<td>Funders Involved</td>
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<tr>
<td>Investment Plans</td>
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</table>

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Amazon basin dams

Number

<table>
<thead>
<tr>
<th>Power (MW)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100</td>
<td></td>
</tr>
<tr>
<td>100-500</td>
<td></td>
</tr>
<tr>
<td>500-1000</td>
<td></td>
</tr>
<tr>
<td>1000-5000</td>
<td></td>
</tr>
<tr>
<td>&gt;5000</td>
<td></td>
</tr>
</tbody>
</table>

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Estimated impacts in the Upper Amazon Basin (Finer and Jenkins 2012)

Table 2. Summary of estimated ecological impact and potential energy capacity from low and moderate impact dams in relation to projected 2020 demand.

<table>
<thead>
<tr>
<th>Ecological Impact (No. of dams)</th>
<th>Low Impact (MW)</th>
<th>Mod Impact (MW)</th>
<th>New Demand by 2020 (MW)</th>
<th>2020 Demand met by low/mod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peru</td>
<td>18</td>
<td>19</td>
<td>42</td>
<td>1473</td>
</tr>
<tr>
<td>Ecuador</td>
<td>10</td>
<td>26</td>
<td>24</td>
<td>1074</td>
</tr>
<tr>
<td>Bolivia</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>127</td>
</tr>
<tr>
<td>Colombia</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>29</td>
<td>51</td>
<td>71</td>
<td>2674</td>
</tr>
</tbody>
</table>
• How to deal with river fragmentation and damming for the current and next century?
• Could knowledge from other world systems provide valuable clues?
<table>
<thead>
<tr>
<th>Type</th>
<th>N</th>
<th>Attraction Efficiency (%)</th>
<th>Passage efficiency (%)</th>
<th>Height (m)</th>
<th>Slope (15%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denil</td>
<td>6</td>
<td>31</td>
<td>32</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Vertical slot</td>
<td>6</td>
<td>83</td>
<td>20</td>
<td>1.48</td>
<td>7</td>
</tr>
<tr>
<td>Pool &amp; Weir</td>
<td>14</td>
<td>58</td>
<td>48</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Naturelike bypass</td>
<td>19</td>
<td>27</td>
<td>79</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Lifts and Locks</td>
<td>7</td>
<td>85</td>
<td>55</td>
<td>11</td>
<td>73</td>
</tr>
</tbody>
</table>

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Fish Passage Congress 2015  
(adapted from Bunt 2009)
<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
<th>Attraction Efficiency (%)</th>
<th>Passage efficiency (%)</th>
<th>Height (m)</th>
<th>Slope (15%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrarchidae</td>
<td>5</td>
<td>68</td>
<td>42</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Salmonidae</td>
<td>11</td>
<td>35</td>
<td>83</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Percidae</td>
<td>4</td>
<td>28</td>
<td>42</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Lotidae</td>
<td>1</td>
<td>83</td>
<td>60</td>
<td>14.5</td>
<td>3</td>
</tr>
<tr>
<td>Esocidae</td>
<td>3</td>
<td>31</td>
<td>63</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Cyprinade</td>
<td>6</td>
<td>25</td>
<td>74</td>
<td>14.5</td>
<td>3</td>
</tr>
<tr>
<td>Clupeidae</td>
<td>17</td>
<td>70</td>
<td>34</td>
<td>13</td>
<td>46</td>
</tr>
<tr>
<td>Catostomidae</td>
<td>9</td>
<td>80</td>
<td>28</td>
<td>1.5</td>
<td>16</td>
</tr>
</tbody>
</table>

(adapted from Bunt 2009)
Efficiency in South American dams:

Yacyreta (lifts): 2 %

Santa Clara (truck and traps): 7%
An open debate: Why do we need fish passages and when they are necessary?

- To maintain biodiversity?
- To sustain migratory species?
- To maintain genetic flux?
- To allow that species can reach spawning areas?
Caocheira de Emas (Mogi-Guassu River) installed in 1920-22 and removed in 1942.

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Spawning in main channels

Eggs and larvae drift

Larvae/juvenile growth in floodplains

Preadult recruitment

Trophic adult migrations

Reservoir

Dam

Spawning adult migrations

Dispersion adult migrations

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(adapted from Pompeu et al 2012)
Almost all fishway studies have focused on efficacy instead of efficiency as the key parameter.
South American fishways efficacy

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Dominant species in Yacyreta elevators

Adapted from Oldani & Baigún 2002
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• Whereas hydraulics has been of concern the hydrodinamic environment at the tailrace or inside the passages has been barely considered
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Figure 9  Borland lock operation.
A. Fish entering the lock
B. Fish leaving the lock
C1. Upper sluice-gate
C2. Lower sluice-gate
Vertival slot in Igarapava dam (Grande River, Brazil)
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Claudio Baigun
Fish Passage Congress 2015
Peixe Angical Dam (Tocantins River)

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Pelecice and Agostinho 2012
Prochilodus nigricans
Oxydoras niger
Hydrolicus armatus
Brycon gouldingi
Leporinus friderici
Brycon falcatus
Myleus torquatus
Piaractus brachypomus
Raphiodon vulpinus
Pseudplatystoma fasciatum
Leporinus trifasciatum
Pimelodus blockii
Semaprochilodus brama
Tometes sp.
Sorubim lima

Lajeado Dam long distance species

Upward/Downward ratio

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Some important questions still without clear answers

• Are classical “rule of thumb” guidelines applicable for rivers with much more flow and dimensions?
• Where fishways entrances should be located based on potential turbine interferences?
• What dimensions should have the entrances?
• What number of fishways we need in very large rivers?
• How many attraction flow is needed for rivers with more than 10,000 m3/s (is the 1-5% rule valid for South American large river dams?)
Two elevators of only 15 m³ each
Entrance to colector channel and lift

Entrance to colector channel and lift
• Think in big: Dams are not the only problem. Reservoirs could be even worst!
• Large reservoirs usually promote irreversible riverscape changes affecting community structure that cannot be restored by stocking.
• Large reservoirs destroy upstream large floodplains that act as valuable growth and rearing habitats for several migratory species and promote high mortality on drifting eggs and larvae.
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Pelecice et al. 2014)
Largest Brazilian reservoirs

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(adapted form Pelecice et al 2014)
(adapted from Pelecice et al. 2014)
From Pelecice et al 2014

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Species composition in Brazilian reservoirs after stabilization

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Fish Passage Congress 2015

Baigun et al 2011
Figure 4. Fish species composition in the landing of artisanal fishery in Itaipu Reservoir, before (1977) and after impoundment (1987 and 1997).  

Frequency of occurrence (%)  

Migraotry species:  
50% of capture

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Agostinho et al 2001
Figure 1. Dominant species by biomass in artisanal fishery landings of the Upper Paraná River before and after impoundment of Itaipu Reservoir. Dominant species prior to impoundment: (a) jauí, Zungaro zungaro, (b) dourado, Salminus brasiliensis, (c) pacu, Piaractus mesopotamicus, (d) pintado, Pseudoplatystoma corruscans. Dominant species following impoundment: (e) armado, Pterodorus granulosus, (f) curimba, Prochilodus lineatus, (g) perna-de-moça, Hypophthalmus edentatus, (h) curvina, Plagioscion squamosissimus. Photographs by E.K.O.
Mean yield in the upper Parana dams: Only 14 kg/ha!!!

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• Think also in small!!
• Small dams (mostly directed to irrigation purposes) are big problems too!
• Small dams are “invisible” as they usually do not have environmental studies or do not consider migratory fish problems.
• Most of small dams are underestimated and built without considering bioengineering criteria.
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Number and Purposes of registered dams

Codes
H Hydropower
S Water Supply
C Flood control
I Irrigation
N Navigation
R Recreation
F Fish breeding
X Others

37641 Dams data corresponding to registered dams only
• In South America is yet not clear or has not been properly assessed how low height dams could affect fish movements and when fishways are needed.

• However small dams are by far more numerous and could also exert catastrophic effects at a basin scale.
Final concerns

• How representative are the available fishways efficiency considering that most of past fishways design were not based on specific bioecological characteristics of neotropical fish?
• When fish passage efficiency should be considered successful in South American large rivers?
• What number of fish do we need to pass to assure a reliable genetic flux and to sustain viable populations?
• Are biologists, engineers and hydrologists in South American countries be prepared to cope with fish passage challenges for incoming dams?
• How to match “engineer scales” with “biological scales” required to gather appropriate information about fishways design?
• What type of modifications should be introduced to improve fishways design taking into account large size migratory species? (location, number, dimensions, hydrological and hydrodinamnic characteristics)
• Are adult downstream migrations critical to maintain viable populations?
• Can tributary be effective to sustain fish reproduction when main channels are replaced by reservoirs?
• Which order rivers should be protected or remain unfragmented regarding fish life cycles?
• How can reservoir barriers effects be reduced?
• How to deal with small dams impacts?
• How to match dams requirements (energy and performance) with land use and climate change in transboundary basins?
• How to match dams requirements (energy and performance) with land use and climate change in large transboundary basins?

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South America

Hydro in operation in South America as a percentage of the total 2 700 000 GWh/year technically feasible potential

- 20.5% in operation
- 79.5% unexploited technically feasible
- 38.8% unexploited technically and economically feasible
- >16 749 MW of hydro under construction in 10 countries
- ~554 000 GWh/year produced from hydro plants (114.4 GW)
- 1600 TWh/year of economically feasible potential
- Hydro supplies ≥ 50 per cent of electricity in 10 countries

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Fig. 2 Global spatial distribution of future hydropower dams, either under construction (blue dots 17%) or planned (red dots 83%).

Zarfl et al 2015

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Fish Passage Congress 2015
Fig. 3 Number of future hydropower dams per major river basin. Red >100, Orange 26-100, Yellow 11-25, Green ≤10, Gray no data available

Zarfl et al 2015

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The future?: Maybe good for biologists and engineers, but bad for fishermen and fish!

THANK YOU!!

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