Fisheries and sustainable hydropower: Issues to optimise ecosystem services delivery

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Outline

- Dam development issues
- Ecosystem services concept
- Case study: Kafue Flats, Zambia
- Alternative options for Mekong
Dam development issues

Global development for:
• Hydropower
• Supply
• Agriculture
• Flood mitigation
Dam development issues

Well rehearsed arguments of impacts

**Impacts of Dams**

**Downstream Impacts**
- reduced biodiversity
- poor water quality
- lower crop production
- decreased fish populations

**Dam**
- blocked fish migration
- disrupted flow of sediments and water
- hazards from ageing dams

**Reservoir**
- contributes to global warming
- displaces communities
- increases water-borne illnesses
- triggers earthquakes
Media responses

A Lifetime of Injustice
History of the Belo Monte Dam

Take Action

Climate change is real and it's happening now. The Green Climate Fund (GCF) is our best chance to help developing countries transition to clean energy. Tell decisionmakers we want clean energy in the GCF!

Thai Villagers Seek Justice
Xayaburi Dam Back In Court

Cambodia's Hydroelectric Question: China Power and the Environment
Cambodia's development and energy security require hydroelectric development.
By Sim Vireak

World Rivers Review
The June issue shines a spotlight on creative and courageous campaigns to protect the world's rivers, with excellent first-hand reporting from dam hotspots around the world.
Reality: Dams will be built to meet society demands for ‘green’ ‘renewable’ energy. But how to minimise impact?
Environmental Impact design

- Avoidance – not fully considered Mekong
- Mitigation – fish passes and turbine design
- Enhancement – aquaculture and stocking
Mitigation measures

Mitigation measures to ameliorate likely impacts focus on:

• in-take and outfall locations,

• fish passage facilities – upstream and downstream,

• ‘Friendly’ turbine design (recognition that only effective way to improve survival is to direct the fish away from the intakes – screens and bypass channels)

• measures to ameliorate the potential impact of depleted reaches – allocation of flows

• Replacement of lost fisheries – aquaculture and stocking
Mitigation-measure – fish passes /fishways

Technical fish passes

- Best for barriers up to 10 m
- Rarely work for dams > 20 m
- Will not pass the diversity and volume of Mekong fishes

. Itaipu Piracema Channel
Mitigation-measure – fish passes /fishways

Effectiveness depends on:

• Fish species in question, water head, design & size of river
• Permanently functional – allocation of flows for bypass channels
• Positioning of the entrance
• Provision of sufficient attraction flows around in-take and outfall locations,
• Adapted to the swimming capacities of the fish

PROBLEM: Downstream migration, especially larval stages
Mitigation-measure – turbine design

Various turbine designs aimed at reducing impact

• Improved turbine design resulted in only marginal reductions in fish mortality,
• Concerns remain regarding leading edge strike, cavitation, pressure effects

Recognition that only effective way to improve survival is to direct the fish away from the intakes – screens and bypass channels
Mitigation-measure – aquaculture and stocking

Aquaculture not compensation for lost fish productivity

- Local fishers no experience in fish farming
- No capital to invest in infrastructure (opens opportunity for entrepreneurs)
- Recurrent costs of seed and feeding
- Introduction of alien species (tilapias and carps)

Stocking does not replace lost fish productivity
Alternative strategies
Need to integrate ecological, social and economic objectives of dam development within political frameworks.

- Ecology and environment
- Economic and social domain
- Political and institutional domain
Integrating ecological and economic objectives

Allows the opportunity to promote the concept of Ecosystem Services

Need to understand motives and drivers of each sector

Maximise positive interaction
Minimise negative interactions

Requires aquatic resource knowledge system

Allows the opportunity to promote the concept of Ecosystem Services

Need to understand motives and drivers of each sector
Ecosystem services
Wide range of **benefits** that a healthy natural environment provides for people, either directly or indirectly (Millennium Ecosystem Assessment).
## Ecosystem Services provided by Mekong

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<th>Supporting services</th>
<th>Provisioning services</th>
<th>Regulating services</th>
<th>Cultural and information services</th>
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<td>Hydropower</td>
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<td>Cultural services</td>
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<td>Links within aquatic ecosystems</td>
<td>Rice and agriculture</td>
<td>Regulation of ecosystem resilience</td>
<td>Mekong giant catfish</td>
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<td>Flooding nutrient dynamics</td>
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<td>Flood management</td>
<td>Assessment of ecosystem resilience</td>
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<td>Aquaculture production</td>
<td>Supply of water</td>
<td>Provision of scientific information</td>
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<td>Pharmaceuticals</td>
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Case Study: Kafue Flats, Zambia
Floodplain
- 255 km long
- 60 km wide,
- area 6500 km²
Wet season flooding

Dry season grasslands
Fisheries – recorded 6000 tonnes per year
Pressures on Kafue Flats ecosystem
Problem related to hydropower development

Kafue Flats

Itezhi-tezhi completed 1978:
Regulating reservoir for Kafue Gorge

Kafue Gorge and proposed lower Kafue Gorge (900 MW)
Depleted reach – 14 km

Proposed hydropower at Itezhi-tezhi with daily hydropeaking 29 – 327 m³ s⁻¹ (= 700 MW)
Identification of flow changes
hydrograph of Itezhi tezhi inflow (red) and out flows (black)
Kafue flow – duration curves

- Unregulated flow
- Regulated flow 1978-2005
- Regulated flow 2006-2010
- Unregulated flow

Flow (m$^3$ s$^{-1}$) vs. Exceedance probability
Trends in fish production

Annual fish production (t)

Mean March discharge (m³ s⁻¹)

Note 7-year cycle before Itezhi-tezhi closed
Encroachment of *Mimosa pigra*

- 1986 - 0 ha
- 1994 - 242 ha
- 2005 - 1952 ha

➤ 6% of land cover

**Issues:**
- Access
- Loss of fish breeding areas
- Loss of fishing areas
Encroachment of Mimosa pigra
Alien invasive species

Nile tilapia

Redclaw crayfish

50+% catches throughout Kafue Flats

Prevalent throughout Flats and not harvested
Management opportunity to use ecosystem services delivery

Recognition Itezhi tezhi hydropower development will occur – political decision

NEED TO OPTIMISE DESIGN AND OPERATION – BUT HOW?
Ecosystem Services provided by Kafue Flats

Supporting services
- Maintenance of genetic, species and ecosystem biodiversity
- Links between aquatic and terrestrial ecosystems – flood cycles
- Links within aquatic ecosystems

Provisioning services
- Production of fish and food from wild stocks
- Hydropower
- Recession agriculture
- Aquaculture production
- Control of hazardous diseases
- Supply of water

Regulating services
- Regulation of food web dynamics
- Regulation of invasive species
- Regulation of ecosystem resilience
- Self purification of water
- Flood control

Cultural and information services
- Recreational activities and tourism
- Cultural services
- Aesthetic values
- Assessment of ecosystem resilience
- Provision of scientific and educational information
Fisheries as a service
- catch including IUU – 30,000 t /yr
- value 40 million US$
- Dependence 150,000 people
Alternative livelihoods based on water demand

Sugar, mining, agriculture
Zambia Sugar Co. 27,000 ha

Fish farming
Production expanding – Kafue fisheries 1000 t -

Issues:
• Production mostly alien species – Nile tilapia
• escape of species
• encroachment on wetlands
Tourism and nature conservation

Kafue lechwe

Economic value untapped
Intrinsic conservation value huge but unrealised
Flow regulation (Itezhi-tezhi) on wildlife and biodiversity – Lechwe numbers in Lochinvar National park

Post Itezhi-tezhi impoundment

$K_1$ before dam construction; $K_2$ after construction of the dam;

Populations mean 1931 – 2005
Strategy for sustainable aquatic resources and fisheries development

• Understand fisheries dynamics – engage with DoF, communities and research institutions.
• Understand hydrological shifts
• Engage with wildlife (charismatic) sectors to promote partnerships
• Engage with other production sectors
  – Fish farming (1000 t)
  – Sugar cane production (27,000 ha)
• Develop co-management initiatives to establish environmental flows/ habitat management
Optimizing use of water for hydropower and Kafue Flats ecosystem services

Ecosystem services evaluation

Optimise overall benefits

Reservoir dependant livelihoods
- Water supply
- Hydropower
- Fisheries

Flow dependant livelihoods
- Floodplain products
- Fisheries
- Recession agriculture
- Floodplain grazing
- Aquaculture
- Biodiversity

Water remaining in reservoir

Flow release
- Duration
- Timing
- Frequency
- Extent

Flow release options

Legislation
- Political imperative

Water availability

Socioeconomic conditions
Potential alternatives for the Mekong case study concepts
Ecosystem Services provided by Mekong

**Supporting services**
- Maintenance of genetic, species and ecosystem biodiversity
- Links between aquatic and terrestrial ecosystems – flood cycles
- Links within aquatic ecosystems

**Provisioning services**
- **Production of fish and food**
- **Hydropower**
- Rice and agriculture
- Flooding nutrient dynamics
- Navigation
- Aquaculture production
- Pharmaceuticals
- Supply of water

**Regulating services**
- Regulation of food web dynamics
- Regulation of invasive species
- Regulation of ecosystem resilience
- Self purification of water
- Flood management

**Cultural and information services**
- Recreational activities and tourism
- Cultural services
- Mekong giant catfish
- Aesthetic values
- Assessment of ecosystem resilience
- Provision of scientific information
Sambor and Xekong hydropower projects in the Lower Mekong Basin
Sambor proposed project design

Dam: 56m High
18km Long

2,600 MW
11,741 GWh of annual energy production
Sambor as barrier to fish migration

- Sambor will erect a 54 m high barrier to fish migration and convert 50 km of flowing river to static lake
- Will totally block fish migrations to critical upstream spawning habitat in the Se San, Sre Pok, and Se Kong rivers
  - At least 86 species are long-range migratory species in the Cambodia part of the Mekong
  - All 86 species will become threatened
Sambor Alternatives 3 and 4
Flood and Sediment Bypass

Opportunity to use bypass channel for fish passage

Requires
• environmental flow
• diversion structures
• Attraction flows
# Xekong hydropower

## Main Features of the proposed Xe Kong Hydropower Projects (From Golder Associates 2014)

<table>
<thead>
<tr>
<th>Item</th>
<th>XK-5</th>
<th>XK4</th>
<th>XK3up</th>
<th>XK3d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated head (m)</td>
<td>188</td>
<td>140</td>
<td>34</td>
<td>17</td>
</tr>
<tr>
<td>Design discharge (m$^3$/s)</td>
<td>146</td>
<td>240</td>
<td>460</td>
<td>568</td>
</tr>
<tr>
<td>Catchment area (km$^2$)</td>
<td>2,615</td>
<td>5,400</td>
<td>5,882</td>
<td>9,700</td>
</tr>
<tr>
<td>Mean annual flow (m$^3$/s)</td>
<td>137</td>
<td>205</td>
<td>240</td>
<td>316</td>
</tr>
<tr>
<td>Total reservoir volume (mill m$^3$)</td>
<td>1,356</td>
<td>3,100</td>
<td>425</td>
<td>486</td>
</tr>
<tr>
<td>Reservoir length (km)</td>
<td>41</td>
<td>92</td>
<td>15</td>
<td>21</td>
</tr>
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</table>
Xekong cascade as barrier to fish migration

- Will totally block fish migrations to critical upstream spawning habitat
  - At least 55 species are long-range migratory species lower part of the Mekong River
  - 17 species found in no other area of Mekong (WWF)
  - Potential loss of large fish production in mid-river area of Laos unless protected
Alternative XeKong Basin Hydropower Development Scenarios – need to protect fish recruitment areas
SCENARIO ONE: Confine hydropower development to the tributaries of the Xekong mainstream, particularly the Xe Kaman tributary.
SCENARIO TWO:
Maintain Xekong #5 or substitute Xekong #5 with several smaller dams in the headwaters tributaries above the current Xekong #5 dam site.
Additional lateral highland tributaries and scale these for maximum hydropower production.
Must protect natural flow regime.
CONCLUSIONS

• Fish passage mitigation is just one tool in a suite of measures to support fisheries.

• Shift science from data-driven outputs to meet policy and management needs.

• Acknowledgement that developments will go ahead - optimisation of resource use.

• Improve mechanisms to communicate importance of fish conservation and fisheries to livelihoods, local economies and food security and influence decision making – use ecosystem services approach.

• Further promote mechanisms to integrate fish and fisheries into the wider ecosystem planning process.