Workshop 4: Lowering turbine mortality by design and management for hydropower plants < 50 m³/s

Roermond (NL) – 5-6 October 2016

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Topics

- Fish friendly turbine
  - Different turbines already available
  - Some are currently tested in situ
  - Others in theory (potentially ?) fishfriendly
  - Towards a common certification?
    - Criteria
    - Protocols

- Management of hydropower plants
  - Targeted shutdown of turbines: Is it possible to target periods of stops to effectively protect fishes in downstream migration, while limiting losses of production ?
  - Reducing mortality by catch and transport

This presentation is based on a literature review provided by the delegations of the ICRP
1. Fishfriendly turbines

1.1. Different turbines already available

Archimedes' screw

More than 10 manufacturers in the world.

Flow : 0,5 to 5,5 m³/s (max 10 m³ / s)
Head < 12 m
Power : < 100kW (max 500 kW)

Several tests :
- SPÄH (2001) 158 fishes (9 species), 4,4% of injuries only on chub and roach.
- KIBEL (2007 et 2008), no damage on smolts, kelts and eels.
1. Fishfriendly turbines

1.1. Different turbines already available

**Archimedes' screw**

Hydrodynamic screw can be considered as fishfriendly if:
- The upstream edge of the turns should not be protruding relative to the edge of the screw
- The upstream edge of the turns must be covered by a bumper
- The gap between the screw and coat must be low (≤ 5 mm)

- **No tests on largest diameter screw**

- **Are the tests of a manufacturer valid to other?**
  - ➔ In France, yes, if previous conditions are met and if there are no other potential sources of mortality identified
1. Fishfriendly turbines

1.1. Different turbines already available

Very Low Head (VLH)


- Flow: 8 m$^3$/s to 27 m$^3$/s
- Head: 1.4 m to 3.2 m
- Power: 100 to 500 kW

Several tests:
- On Tarn river at Millau in 2007 and 2008 on a first generation (2.5 m; 20 m$^3$/s): 7.7% of mortality for eels and 3.1% for trouts.
- On Mosel river at Frouard in 2010, on a second generation (2.4 m; 22 m$^3$/s), 244 eels (61-100 cm): no mortality and 2% of non lethal injuries.
- On Tarn river at La Glacière in 2013 (1.8 m; 22.5 m$^3$/s, 1200 fishes – 3 species): no mortality for small trouts (<26 cm), 1.1% to 4.4% (according to blade opening) for biggest trouts (42-57 cm)

⇒ In France, VLH are considered fishfriendly for eels and smolts, but not for kelts

1. Fishfriendly turbines

1.2. Recently tested in situ

Turbine Pentair Fairbanks Nijhuis/FishFlow Innovations

Flow : 1.5 m$^3$/s to 150 m$^3$/s (possible up to 340 m$^3$/s with a propeller diameter of 8 meters)
Head : 1 m to 15 m
Power : 100 to 500 kW (up to 4 000 kW)

Two tests :
- Winter et al 2012 (Institute IMARES) alongside pumping station Leeghwater at Buitenkaag (NL), with a head of 5.5 m and a discharge of 4.5 m/s. Six trials were carried out 79 eels per trial : no direct mortality was found, nor any abnormal swimming behaviour or severe injuries.
- Vriese (2015) with very low head (0.29-0.85 m) and flow (0.6-0.8 m$^3$/s), as a down-scaled model for tidal plant : 580 fishes, 3 species. 4% mortality on pike perch (<23 cm). 0.5 % on trout. No mortality for yellow eels (<34 cm).

⇒ Fishfriendliness for higher head (> 5 m) and smolts ?
⇒ Validity of projection from results obtained on down-scaled model ?
1. Fishfriendly turbines

1.3. Turbine in théory fishfriendly

**Alden turbine**

Flow : 15-80 m$^3$/s
Head : 6 m to 35 m

Tests with a down-scaled model (1 : 3.25), 12 to 24 m head, 30 to 50 m$^3$/s, diameter 1.2 m, 40 000 fishes, 6 species:

However, extrapolation of the results to eels representative of the stock migrating downstream (600 to 1 000 mm) was considered too uncertain. And so need to be validate by a pilot test predictions.

In Amaral 2015 (Bienne Symposium)
1. Fishfriendly turbines (?)

1.3. Turbine in théory fishfriendly

Lucid Spherical Turbine

Paddlewheel

Hydrolienne
1. Fishfriendly turbines

1.4. Towards a common certification?
Standardize protocols permit to avoid a multiplication of tests on a same turbine

**In France**, at minimum:
- Different trouts (or salmon) size:
  * 13-18 cm as smolt
  * 22-27 cm as adult trout
  * 40-60 cm as kelts (potentially longer [60-90cm], but difficult to find a large number of such fish)
- Eels > 60 cm
- batch size = min 100 fishes (+ control batch)
- Test to perform in the most risky conditions (head, discharge, rotation speed, blade opening) to be valid for a wide range of sites.

**In The Nederland**
- Dutch government stating a mortality rate of max. 0,1 % per passage.
- Possibility of testing scale model turbine 1:20,
- 4 species recommanded: yellow eel (20 cm), smolts or trout (12 cm), pike perch (16 cm) and flounder (10 cm). All obtained from fish farms.
- batch size = min 100 fishes (+ control batch)
Intake with fish screens

Hydrodynamic screw testing at Ashburton (in Kibel, 2007)

Test site of Pentair Fairbanks Nijhuis near Maurik at the Nederrijn.

VLH testing in France
Photos in Baran et Courret 2013
1. Fishfriendly turbines

1.4. Towards a common certification?

These protocols do not assess the delay fish migration upstream of the turbines and the increased predation risk due to disorientation after passage of fish through turbines.

The impact of dams on habitats and migration delays (upstream and downstream migration) must also be considered.
2. Management of hydropower plants

2.1. Targeted shutdown of turbines: Is it possible to target periods of stops to effectively protect fishes, while limiting losses of production?

Acceptable shutdown durations must be determined through negotiation with each operator and for each installation.

In France, ongoing research at Tuilières on the Dordogne (Flow = 320 m$^3$/s):

- Long development of the model (5 years of experimental fisheries + Telemetry + ARIS tracking camera) still ongoing
- 28% to 43% of nights with stopping the turbine during the target period (early September to late January or late February depending on the year) for a rated efficiency of 75% -95% depending on the year

Figure extraite de De Oliveira et al. (2015)
2. Management of hydropower plants

2.1. Targeted shutdown of turbines: Is it possible to target periods of stops to limit losses production?

The Migromat® biomonitor is based on the fact that silver eels (not for other species) held captive in basins supplied with water from the river show signs of enhanced activity during peaks in downstream migration.

Tests were run in Ireland on River Shannon from September 2008 to March 2010 in Killaloe. The results were mediocre: enabled 14 to 29% of the eels migrating downstream to escape.

In Baran et Basilico 2011 (http://www.onema.fr/IMG/EV/meetings/management-plan-to-save-the-eel.pdf)
2. Management of hydropower plants

2.2. Reducing mortality by catch and Transport

Used in the USA: Chinook and Steelhead smolts are collected in bypass facilities at Lower Granite, Little Goose, Lower Monumental and McNary dams and transports them to release sites below Bonneville Dam.

Also used in France on Garonne and on Neste for salmon’s smolts, with two trapping systems at two hydropower plants, to bypass 21 plants.

- The difficulty is to design an effective trapping system, even during high flow events!
2. Management of hydropower plants

Reducing mortality by catch and Transport
2. Management of hydropower plants

2.2. Reducing mortality by catch and Transport

Exemple of River Mosel, In Kroll (Fish passage 2015)
Conclusion and questions

- Is fishfriendly turbines do not allow to equip dams that could have been erased? Is this turbines not increase predation?

- Is it the shutdown of turbines technically feasible? Is it possible to improve forecasting systems of downstream migration events? What about other species than eels?

- Is the “catch and transport” system efficient? Can it be implemented everywhere? What about other species than eels?

- What is the current state of technology?
- What are the black spots?
- What are the new ideas?
- How to improve in the next few years?