Fish avoidance to infrasounds: first industrial applications and new developments

With ProFish, comply your industrial activity with legal protection of aquatic fauna

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The issue: fish mortality at industrial water intakes

Cooling water intake:
River: 2.5 T of fish killed/year/1000 MW
Estuary: 7.5 T of fish killed/year/1000MW

Hydroelectric water intake: 5 to 30% migratory fish killed per site

- Demographical threat for migratory species like Atlantic salmon and European eel

- European legal context: WFD + EU regulation on eel protection
- USA: CWA 316 b Section, concept of “best technology available”
Different types of behavioural barriers have been developed

Principle: induce an avoidance behaviour by the mean of a stimulus

Light

Bubbles

Sounds

Electricity
Infrasounds:
- Low frequency sounds (< 20 Hz)
- Water particle displacement/acceleration
- Naturally emitted by swimming fish (Enger et al. 1989)
- Heard by all fish species (otolith acceleration sensitivity)
- Natural alarm signal for fish
- Immediate and systematic fish avoidance response (small shock wave)
Infrasound have been developed by Prof. P. Enger and Prof. O. Sand at the University of Oslo

Both in laboratory conditions and in small natural experimental sites, this team has demonstrated infrasound efficiency to elicit avoidance responses among various fish species

**Most known references:**
Avoidance of young Atlantic cod in laboratory conditions (Sand & Karlsen 1986)
98% repulsion on Atlantic and Pacific salmon smolts (Knudsen et al. 1992 & 1994, Sand et al. 2001)
50 % of deflection (3 m range) on downstream migrating European silver eels (Sand et al. 2000)
Avoidance of 0+ cyprinids (Karlsen et al. 2004)

No other behavioural barrier benefits from a so high scientific background validation
In 2003, we conduct larger scale experiments in a lake and at the cooling water intake of Thange.

Distance from echosounder  

16 Hz Infrasound stimulus

1) 10 m repulsion on 0+ cyprinids and percids in lake

2) More than 80% of fish impingement reduction around the two generators of the intake

Sonny et al. 2006
From laboratory tests to the industrial development

In collaboration with:

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Video observation in a flooded quarry (La Gombe - Belgium)
Two symmetric pistons
180° out of phase
5 to 16 Hz

Synchronisation

Water velocity : 0.3 m/s
Annual fish mortality : from 10 to 25 T
Main species affected :
95% = young-of-the-year cyprinids and percids (< 10 cm)
6 generators (12 m interval) pulsing in a sweep mode between 10 and 13.5 Hz
Sonar counting during 15-min infrasound ON/OFF sequences
Counting directly downstream the intake, no delay in the counting
Fish counting during 10 ON-OFF comparison of 15 minutes

Filtered data with Sonar 5: exact “live” effect
During the off sequence, fish appear more clearly and can be counted

15 min ON      15 min OFF
Focus only on young fish (< 10 cm)
Infrasound OFF : 103 fish counted over 10 sequences
Infrasound ON : 21 fish counted over 10 sequences
Efficiency : 80% = target threshold (Verelst 2009)

Confirm the efficiency of 84% observed in 2003 on the same intake with two units
Sonny et al. 2006
An independent bureau (FLUSS) confirmed more than 80% of efficiency on young cyprinids by counting on the filtering drums, after an adjustment of the generator depth, at the 12-m wide cooling water intake of Lingen.

*Depth effect related to the intake or the fish position?*
Third application: silver eels guidance at Biron power station, Gave de Pau River, France

Eel behaviour by radio-telemetry
EDF-R&D, CNR & ONEMA
5 machines in 2008, 8 machines in 2009
No real collaboration with us, we have no access to data so far
We heard that no obvious guidance has been observed

Approximate current directions

What we learned:
- To guide silver eels towards the spillway, eels had to swim against the current along the second half of the boom
- As long as the bypass discharge on the spillway is too low, the abstracted current of the power plant remains the most attractive
- By then end, we wanted to obtain a guidance which corresponded to a “swimming against the current behaviour”. We understood that this can’t be achieved with our system for eels
- Previous results on silver eels showed that lateral guidance within the main current could be achieved (Sand et al. 2000)
1. Lateral avoidance response of American silver eels to infrasound

Partner: Hydro-Quebec

Eel migrating behaviour observed in a cage (50 m long) in an arm of the St Lawrence River.

Summer 2010 objective:

Observe lateral avoidance of silver eels within the main current of the cage

Problem: the size of the experimental cage brought limit to observations
Eel monitoring: fyke nets + video records of events (passage)
a) Fyke nets trapping comparisons

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Catch in fyke nets after 24h of release</th>
<th>Catch in fyke nets in the last 24 h of the experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Hz</td>
<td>5/18</td>
<td>1/21</td>
</tr>
<tr>
<td>10 Hz</td>
<td>3/4</td>
<td>2/3</td>
</tr>
<tr>
<td>12 Hz A</td>
<td>3/6</td>
<td>4/8</td>
</tr>
<tr>
<td>12 Hz</td>
<td>3/5</td>
<td>5/11</td>
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<tr>
<td>14 Hz</td>
<td>6/10</td>
<td>2/6</td>
</tr>
<tr>
<td>16 Hz</td>
<td>2/7</td>
<td>7/11</td>
</tr>
</tbody>
</table>

100 % = 1 cm/s² = acoustic threshold Sand et al. 2000

- Very low eels trapped in the fyke nets, no statistics possible
- As the two corridors are 3 m wide, we could have missed a short avoidance effect
- No conclusion can be take from this counting
b) Automatic video events counting

- More events to analyse but no real corroboration between the events counted by the different cameras
- No direction associated with an event detection, so it is more activity than swimming direction
- No real conclusions can be taken

The experimental setup was not well appropriate, so we want to conduct a new experiment more well prepared to study infrasound and maybe some other additional technologies (2011 - 2012)

Info: Hydro-Quebec has developed a very efficient ultra-sound barrier to deflect shad (Alosa spp.) that we might bring as a new available deflecting technology
2. Effects of infrasound on fish in the Elbe estuary

Study made by Marine Science Service for DOW (Stade)

Combination of infrasound with the Passavant Geiger electrical fence

Target species: Shad (Alosa)

Data not yet available, but both systems could be installed on the future cooling water intake next year...
3. The next big project under progress: cooling water intake of Wilhelmshaven, North Sea, Germany (GDF Suez)

12 machines installed off shore in combination with the Passavant Geiger electrical fence

Marine application

Scheduled in June 2011
4. Adaptation of an upstream mechanical floating fine mesh fish barrier associated with an automatic fish counting system for guiding and monitoring downstream migration
- On river cooling water intake, the system has a good potential on 0+ drifting cyprinids (80 % as a threshold) : we can go for such sites

- Adaptation on hydropower and silver eels did not bring yet convincing results, but we are still working

- Lot of research still has to be done : frequencies, amplitude, acoustic amplification, directional effect, specific thresholds, ...

- We explore other complementary technologies to combine with our system

- We are always open for new tests, guided by a scientific validation approach (salmon smolts, lampreys, ....) and new partners!
Connected projects:

- Fish turbine passage studies
- Impact measurements of water intakes
- Fish populations evaluations (lake, rivers, estuaries) by sonar and CEN nets
- Sonar SIMRAD and DIDSON fish studies
- Design of multi-specific fish passes

Through a partnership with Genivar, Canada:

- European distributor for Ichtyos©: Automatic fish counting system in fish ladder

- Bird and bat flying corridors detection by the use of automatic radars (25 km range) for wind turbines projects
Many thanks for your attention!!