DHI CASE STORY

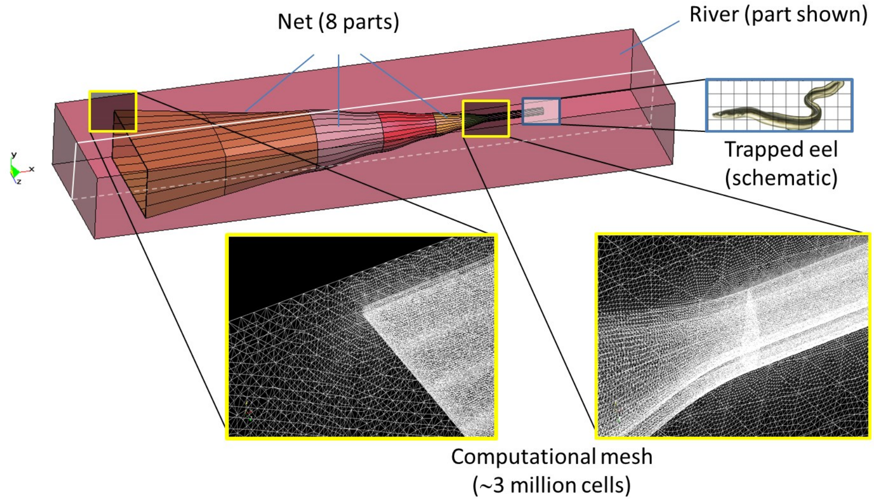
UNDERSTANDING THE EFFECTS OF RIVERINE FORCES ON EELS

Using CFD modelling for the hydropower industry

Fishermen in the Weser River at Dörverden, Germany noticed a large number of injured and dead eels in their fishing nets. They complained that the turbines of a nearby hydropower plant hit the eels, causing the observed injuries. Statkraft Markets GmbH – the plant operator – asked us to investigate the injuries involved in catching the fish with nets, and the forces involved therein. Using Computational Fluid Dynamics (CFD), we thoroughly analysed the forces exerted on eels. With this data, biologists determined that sustained pressure from the fishing net could in fact, be the actual cause of damage to at least some of the eels.

INJURED AND DEAD EELS

Local fishermen caught severely injured and dead European eels (Anguilla anguilla) in Weser River at Dörverden, Germany. The eels were caught downstream of a hydropower plant operated by Statkraft Markets GmbH. Some fishermen asserted that the plant's turbines caused the eel injuries. Consequently, Statkraft Markets GmbH asked us to investigate alternative possibilities, including whether the eels could have been injured, simply by being caught in the fishing nets. We used CFD modelling to analyse the river flow through and around packed eels caught in nets to estimate the force exerted on them.



The computational domain: fishnet (consisting of eight parts) within river (in pink).

SUMMARY

CLIENT

Statkraft Markets GmbH

CHALLENGE

Uncertainty about the cause of injury to a large number of eels caught downstream of a hydropower plant

SOLUTION

Using Computational Fluid Dynamics (CFD) modelling to determine if forces exerted on the eels while in the fishing net, could result in the observed injuries

VALUE

Helping to accurately evaluate the impact of fishing nets on eels

LOCATION / COUNTRY

Dörverden, Germany

PROPER NUMERICAL PARAMETERS: FLOW, FISH AND FISHING NET

As in any model, the critical part was to describe the system with meaningful physical parameters, and to calibrate their values:

- turbulence parameters reproduced correct velocity profile, typical turbulence intensities and proper energy dissipation in porous structures (k-ϵ model of turbulence)
- empirical relations were used for porous properties of packed fish and fishing net (Darcy law)
- computational mesh was very fine around water-porous boundaries and around river bed (~3 million cells)
- uncertainty analysis showed that changing the parameters within physical bounds had a low impact on results

FORCES AFFECTING THE EELS

Using the porous and turbulent solvers of OpenFOAM, we calculated turbulent flow in the system and determined the total force on eels. The force on a single eel – pressure at the eel multiplied by the area of the eel – consists of:

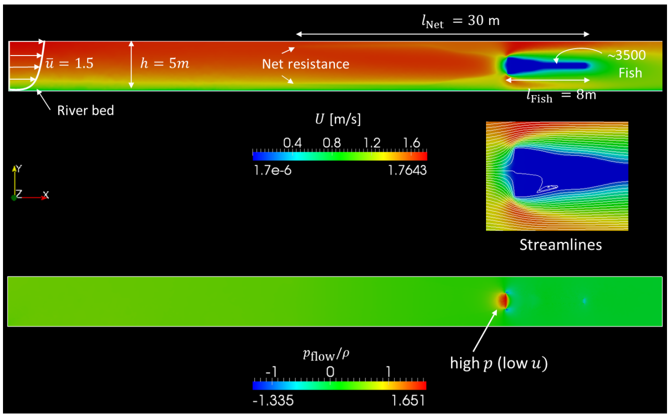
- environmental force
- flow resistance force
- turbulence force
- fishing net force

In terms of pressures, the environment (weight of the river and the atmosphere) exerts pressure on the eels even when they are not caught. The pressure is about 10,000 kg/m^2 (or 1 bar).

Flow resistance is related to fluid inertia. As the fluid is stopped by the densely packed eels, it imparts momentum onto the eels (Bernoulli's law). It is about 3% of environmental pressure.

Turbulence imparts friction due to turbulent vortices produced at the water-porous boundary. It accounts for about 2% of environmental pressure.

A fishing net can generate high local stress on the eels because of the net's small twine pressing against them. The forces exerted depend on the twine's density. It normally ranges about 2-4% of environmental force. Under certain conditions (for example, when the net is pulled from the water), it can reach up to 300%. This is because the gravity pushes the eels at the top of the net onto the eels at the bottom.



Simulated velocity and pressure. Highest pressures are at the front and at the back of the fish volume where the velocity has a sudden drop (inset: streamlines around the fish volume, showing only small velocities within the fish).

POSSIBLE INJURIES AND DEATH OF EELS

Pressure alone, however, is not the sole determinant of eels' injuries and potential death, since they can withstand pressures up to 100 bars or more (depths of 1000 m). Eels are adapted to habitats of calmer waters and can hardly escape streams with velocities higher than 0.3 m/s. Being trapped in high currents for prolonged period of time — that is, in a fishing net — they can run to exhaustion and die.

In our CFD simulations, calculated current speeds are substantially stronger than the critical 0.3 m/s. They range from 1.6 - 1.9 m/s at the front to 0.8 m/s at the back of the fishing net. Based on these results, exhaustion may have indeed contributed to death of some of the eels.

Typical eel injury from the net
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In addition, it is possible that the fishing net itself caused some of the observed injuries. Under large tensile loads (for example, when packed with eels), each part of the fishing net becomes unyieldingly hard. Eels pressed into such a tight net for hours are likely to suffer skin lesions and bruises. Known turbine damage does not account for these types of injuries. Based on this data, biologists determined that the injuries sustained by at least some of the fish could have been caused by the fishing net.

CLIENT TESTIMONIAL

"I would like to again briefly express my appreciation, since DHI has done an excellent job in my view."
Maik Thalmann —Power Plant Manager —Statkraft Markets GmbH

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