Hydropeaking: Norwegian rivers need to be better protected from hydropower plants

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Credit: AI-generated image (disclaimer)

"Why do we allow hydropower plants with outlets into rivers to operate with rapid water level changes when Norway has plenty of power plant outlets that flow into the sea?" asks NTNU researcher Jo Hallvard Halleraker.

The month is May and the spring sun shines over the Otra River where it flows serenely for the last 15 kilometers before flowing into Kristiansand's eastern harbor. The riverbed gravel contains this year's production of salmon eggs, about to hatch. Hundreds of thousands of small salmon fry will soon see the light of day. But their survival is not a given.

"When the water level drops in the spring and early summer, we can see the spawning redds teeming with fry. There's lots of feeding activity ensues as seagulls help themselves to the fry," says Jostein Mosby, head of the Otra laxefiskelag, the local salmon association.

He has been following the river from the time when it was heavily polluted by industrial discharges until the present day. As the river's water quality improved, a viable salmon stock has returned. But now the power industry poses a danger to Norway's wild salmon, which were recently classified as near threatened.

"Fish can't live on land. And they can't withstand rapid water level fluctuations. Salmon fry aren't mobile," says Mosby.

Eggs and fry trapped in puddles

When power plants farther up the watercourse cut back on production to save water, the downstream water level drops where the salmon spawned in November. The roe (eggs) or fry are left high and dry in their gravel spawning redds, and the fry become trapped in the gravel as the surrounding riverbed dries up.

"The roe stay in the gravel depressions after spawning in November and until they hatch in April and May. The fry with their yolk sacs remain in the gravel beds. If their beds go dry due to reduced winter water discharge, they freeze. We're talking about fry with gills, so once the

eggs have hatched, they need water to breathe. If you change the water level too fast, the fry don't have time to relocate. They can quickly get trapped in puddles that eventually dry up," says Mosby.

Varying water levels have major consequences

A study of Norwegian hydropower production conducted at NTNU now shows that far more rivers are exposed to the environmental consequences of so-called hydropeaking than previously thought.

Hydropeaking is used to describe when a hydropower plant produces power to meet short-term variations in the market demand for power or to stabilize the power grid.

Hydropower plants adjust their production to the varying market demand and power prices, so the amount of water discharged into the rivers below the power plants also fluctuates, with big peak flows (hence the name) but also periods when flows are suddenly stopped.

"Several analyses show that the vast majority of power producers use price optimization. They ramp production up or down depending on price and the available water volume," says Halleraker. He is currently a guest researcher at NTNU's Department of Civil and Environmental Engineering.

Hydropeaking changes a hydropower plant's operating pattern. Instead of steady flows, the power plant causes abrupt changes in water flow conditions. Hydropeaking intensity can vary greatly.

More than 3,000 kilometers of river affected

Halleraker and his fellow researchers have reviewed environmental risks

associated with sudden water flow changes from all of Norway's hydropower plants. They have analyzed all of the production and water flow data that is publicly available.

The study, which was recently published in the academic journal *Science of the Total Environment*, shows that more than 3,000 kilometers of river courses today are impacted by hydropeaking of different intensities from 802 hydropower plants.

At the same time, half of the power plants in Norway (larger than 10 MW) have outlets into fjords or reservoirs, which normally dampen detrimental ecological effects. These power plants are located primarily along the coast of western and northern Norway.

"Why do we allow hydropeaking by power plants with outlets into rivers, which can lead to major damage to freshwater ecology, when Norway has plenty of power plants with outlets other than rivers? Norway is sitting on a gold mine with more than 50% of Europe's regulated hydropower resources. More than 80 TWh of these power plants, or 57%, have direct outlets into fjords and lake reservoirs without the known downstream ecological impacts," says Halleraker.

Eggs and fry are left high and dry in the gravel bed, and fry are caught in puddles when the riverbed around them dries out. Credit: Steven Philip

Fluctuations also widespread in small power plants

The study shows that the problem of sudden changes in river water levels due to hydropeaking is also widespread in many small power plants.

"Hydropeaking is most often associated with the variable operating practices of large impoundment facilities. But a lot of small power plants engage in price optimization, which can be as serious for biological diversity as in larger watercourses," says Halleraker.

He believes that the hydropower industry needs to adapt its power production to ensure ecological sustainability and incorporate more modern measures.

"We need a better national strategy to optimize hydropeaking so that we can reduce the harmful ecological effects of watercourse operations by hydropower plants with outlets into rivers. Operating these power plants more for base load would be one way to achieve this. If we run into a socially critical need for hydropeaking to secure the energy supply in a given area, we can make it more ecosystem-based by establishing a damping reservoir between the power plant outlet and the river," says Halleraker.

However, this is an expensive and space-consuming solution and has so far hardly been studied for Norwegian watercourses.

Greater scope than scientists thought

NTNU professor Tor Haakon Bakken concurs with Halleraker.

"Halleraker's work shows that the extent of hydropeaking is greater than we thought," Bakken says.

From 2009 to 2016, Bakken led the EnviPEAK—Environmental impacts of hydropeaking—project. Researchers investigated how rapid and frequent changes in water level and water flow spread downstream into rivers when hydropower plants ramped production, and what ecological consequences these practices have.

The project resulted in advisory guidelines to managers on how negative environmental effects can be reduced by implementing more ecosystem-based hydropeaking, such as by ensuring adequate minimum flow.

"One of the rivers we studied was the Nidelva in Trondheim, where we have outlets from the Bratsberg and Leirfossene hydropower plants. They're located a few kilometers from the city center. The Nidelva uses a hydropeaking regime, but in a way that limits the environmental impacts. The main reason things are going relatively well there is that the minimum water flow is high, at 30 cubic meters per second. This establishes a relatively high minimum water level, so only limited areas dry up when the power plants stop production," Bakken says.

"Some other places don't have any requirements for minimum flow. When a power plant abruptly stops power production, it's like a crane that is stopped quickly. Large areas of the riverbed can go dry, and fish—all living organisms, actually—get stranded. This is a major problem with hydropeaking," says Bakken.

Energy reserve for Europe

"I used to say that we could tell by looking at the river if it was windy in Denmark," says Mosby.

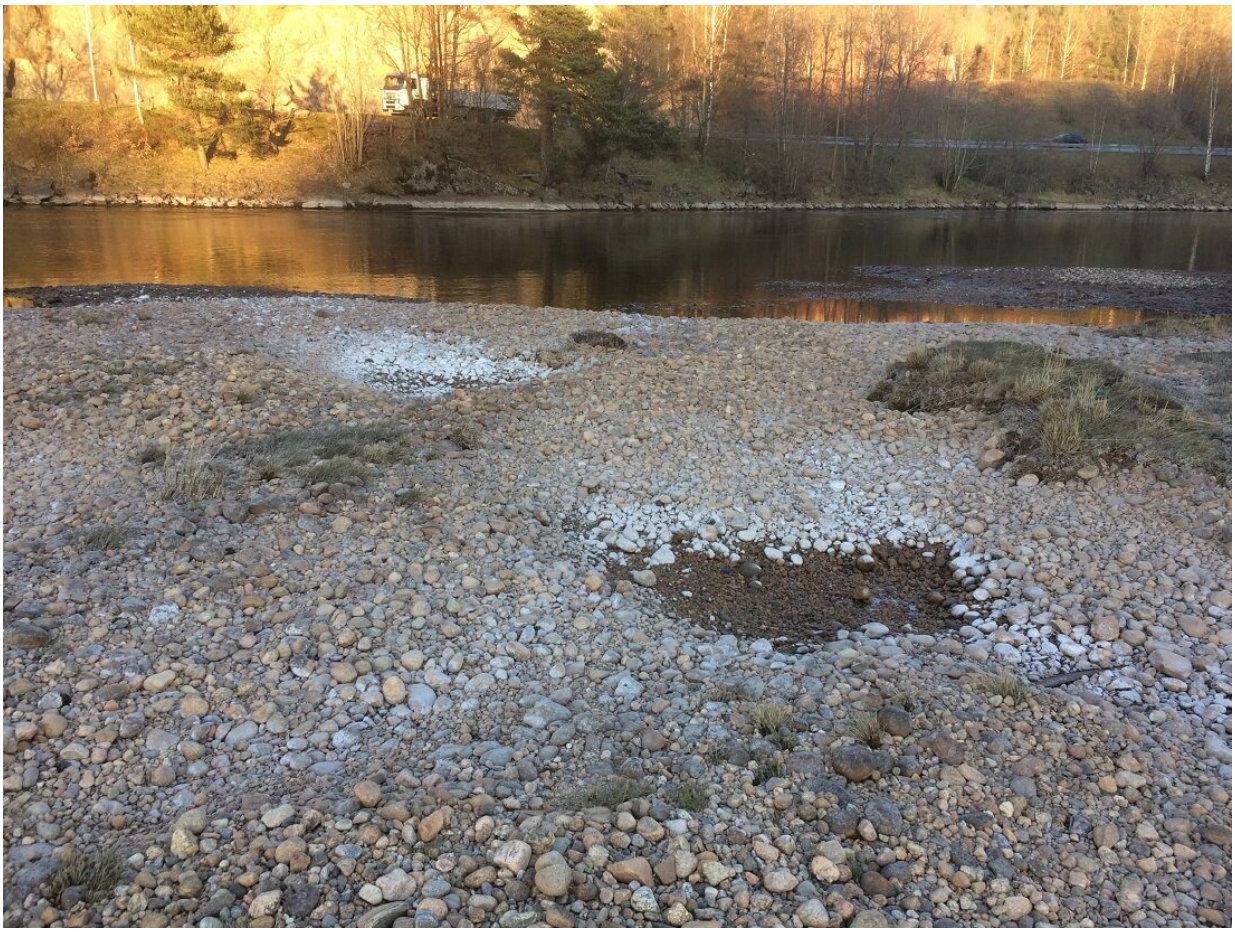
Norwegian hydropower is expected to become increasingly important for the European power market. It could become key as a source of reserve power as the EU transitions energy production to more renewable energies like solar and wind. These sources produce power that varies with the weather conditions and have no way to "fill the reservoirs" like hydropower does.

For the Otra river, the water level itself kills roe and fry as much as the rapidly changing flow reductions do. The river association has taken action to monitor whether the hydropower plants are complying with the regulations.

"We've seen fewer of the rapid fluctuations in water flow in recent years, perhaps because we've been 'on it' and told regulators when we observe that the water level is starting to get alarmingly low. The Otra salmon association has its own water level logger. Along with a lot of our own investigations, this tool has given us important data," says Mosby.

But he is still worried about this year's salmon fry in the river. High power production through the winter combined with little snowpack and precipitation means that the risk is high that the power plants will now need to save water.

"Yes, we're worried about the salmon," says Mosby.



The periodic draining and drying up of rivers is a problem. Credit: Jostein Mosby

New conditions for rivers and water flow

In the next few years, the authorities will be dealing with hundreds of cases as hydropower conditions are revised in the older watercourse regulations. One power plant that has already had its terms changed is the Trollheim power plant on the Surna river.

The Surna holds national salmon river status. This river has been subjected to sudden draining several times due to halts in power

production. In 2008, between 500,000 and one million fry died as a result of an accidental shutdown in the Trollheim Hydropower turbine that caused an abrupt drop in the Surna's downstream water level.

Statkraft power company, owned by the Norwegian state, subsequently installed a bypass valve to counteract such abrupt reductions during minimum flow periods. On 5 March last year, the government adopted new licensing terms for the watercourse. However, the government has elected not to follow all of the Norwegian Water Resources and Energy Directorate's (NVE) proposals for ensuring environmentally safe hydropeaking operation in the river.

"Hydropower plants with reservoirs and regulating capacity give the Norwegian power system great flexibility. Measures that limit this flexibility lead to challenging trade-offs between environmental benefits and the public interest in considering security for the electric power supply," said Tina Bru, then-Minister of Petroleum and Energy, when the new licensing conditions for Surna were announced.

Potential power loss for 1,800 households

The Trollheim hydropower plant is owned by Statkraft and is one of the key reservoir power plants in Central Norway. Statkraft says they are satisfied that flexibility and regulatory ability were adequately addressed when the government made its decision, even though the revisions have resulted in a power loss of around 36 GWh a year, amounting to electricity consumption equivalent to 1,800 households.

"The new conditions include a discharge restriction that varies throughout the year. This is in line with how Statkraft already operates. We've developed this practice with researchers from NINA and SINTEF. We've made an impact using knowledge-based operating practices that we have followed for over 10 years. They ensure a secure

supply of electricity in Møre og Romsdal county," says Knut Fjerdingstad, press spokesperson for Statkraft.

He says Statkraft generally supports the aim of the term revisions and is positive about environmental improvements where the benefits outweigh the costs to society.

"Statkraft believes it is important to take a holistic approach to trade-offs between environmental considerations and consequences for the social benefits that hydropower delivers through regulated, climate-friendly power and flood mitigation capacity. We have to look at the consequences of the condition revisions to the power system and power grid operations as a whole," says Fjerdingstad.

He does not want to comment on Halleraker's research. But he states that Statkraft has been actively involved in research projects under the auspices of the Research Council of Norway. These projects—which include the EnviPEAK project—are studying possible measures to mitigate the consequences of how power plants with outlets into rivers regulate their power.

"Statkraft and the managing authorities have used the results from these research projects in their operational practices and in revising licensing conditions for a long time," says Fjerdingstad.

Variation possible in some rivers

Carsten Stig Jensen, NVE's section manager, tells Gemini that in some places power plants with outlets into rivers are acceptable to use in conjunction with variable flow patterns.

"Environmental consequences of variable operating water flow are a topic in several ongoing revision cases where specific mitigating

measures are being considered for each individual case. In new development cases, conditions are set to ensure that the power plant is operated in a way that doesn't cause significant negative environmental impacts. Where necessary, we require that all water level reductions take place with smooth transitions, preferably specified as a certain lowering rate. The limits for water flow that may be set are considered specifically for each individual case, both for new development and in the revised conditions for older concessions," Jensen says.

Could lose reputation as sustainable

Halleraker believes solving the dilemma between the need for enough power at the right time and the need for environmental adjustments to ensure a sustainable renewable energy industry is critical. These issues must be weighed in the upcoming revision cases in line with similar processes in Europe. He worries that Norwegian hydropower risks being branded as less sustainable in the EU context if we do not think in new ways.

"Even renewable and clean hydropower needs environmental mitigation strategies so that we can refer to them as sustainable. This is spelled out in the EU taxonomy and referred to in the relevant Norwegian legislation that was passed just before Christmas last year," says Halleraker.

More information: Jo Halvard Halleraker et al, Assessment of flow ramping in water bodies impacted by hydropower operation in Norway—Is hydropower with environmental restrictions more sustainable?, *Science of The Total Environment* (2022). DOI: 10.1016/j.scitotenv.2022.154776

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