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Summarized research: facts on eel mortalities at hydropower stations and possibilities for and costs of mitigation

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Summarized research: facts on eel mortalities at hydropower stations and possibilities for and costs of mitigation[1]

Estimations of eel mortalities caused by passing a hydropower station range from almost zero to 100%, making generalized statements very hard and sometimes misleading. The range looks very different depending on each location, turbine type, size and speed. A slower flowing river with relative low dam height using Kaplan turbines can for example give a range of 8% to 30% mortality. The numbers from recent research actually show that more eel survive than previously assumed. Not only the type of turbine and detailed on site construction matter but also its usage or current speed of the turbine at the time of passage. Eels are not just being killed when passing a turbine, but they are also trapped and eventually killed on the steep bar racks in front of the water inlets to the turbines.

Also and important to note is that estimations/models used are not sufficiently considering actual eel production/recruitment to upstream areas meaning that mortality in number of eels are likely overestimated. Estimations must better consider recruitment/river production to show how many eels can be saved at power stations. Currently, the problem of dam and hydropower mortality of eel is almost entirely manmade because of intentional release of eels upstream.

The mitigation solutions tried and verified give good indication of success, over 90% of eel survive passage in some cases. Therefore, prioritizing the right waters to maximize effect of passage measures using grids is critical.

Available solutions and costs for mitigating eel migration in water bodies with dams

Ongoing research, particularly in Sweden over the past 5 to 10 years have shown that we have the knowledge and tools for mitigation, we know what to expect from measures and we know the limitations and impacts on production. In short, we know how to handle small to medium size dams but at larger stations its more difficult and costs rise fast. The latter is important since even though a larger dam may kill many eels, using the same funds could be used to improve migration in many smaller systems that will save more eels. More out-migrating and up-migrating eels with same amount of money.

We know what to do

Swedish studies show that in small-medium size dams (< 88 m3/s capacity) and turbines improve the survival and passage of eels to at least a minimum of 50% and evidence show up to 90% survival passing the dam. Large up to very large dams with as much as 900m3/s capacity have more difficulties both regarding construction and safety issues.

The measures can be rather simple but depend greatly on location and physical characteristics of each site. However, all tested and installed measures regarding downstream migrations are linked to:

- Fine grid (15-18mm bar spacing) racks in sloped position (30-35 degrees), blocking and directing eels/fish away from turbine inlets
- Escape openings sending fish pass the dam, including spillage of water
- Escape hatches including a collection/catch facility e.g. to transport fish below dam
- Timed production limitations and manipulated water flow speeds

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[1] this text is an attempt to compile and translate results from research done during a multiyear project in Sweden called *"Krafttag ål"* Data and examples are based on the project reports. *https://www.energiforsk.se/program/krafttag-al/*

- Large catch devices upstream e.g. so called stow nets

Measures to improve upstream migration have also been tested and in some cases such measures are mandatory under national law, e.g. Denmark. Recent studies suggest that the only really functional measure that include validated increased amount of eel recruitment upstream dams is the nature like fish passage ways. Other measures, including mandatory eel ladders etc, do not seem to have intended effect and does not increase amount of eels in upstream habitats (*publication of article in peer review 2018).*

Example solutions

The table 1[2] is showing examples of measures installed with basic facts of each site. The costs summarized below are from these few examples in Sweden and are focused on downstream mitigation. A very important and common problem for all installations is keeping the racks/grids clean from debris. All installations have some kind of system for cleaning in place. Also, ice during end of winter is a big problem but both issues are present at any power plant and according to a survey, it does not seem as the installed more sloped grids have made problems worse than before.

River	***Ätran***		***Emån***	***Mörrum***	***Rolfsån***	***Säveån(Göta Älv)***
	Herting	**Ätrafors**	**Övre Finsjö**	**Granö**	**Ålgårda**	**Hedefors**
Capacity (m^3/s)	43	72	14	60	15	32
Rack type*	β	α	α	α	α	β
Rack material	composite	steel	steel	composite	steel	steel
grid/rack bar spacing (mm)	15	18	18	18	15	15
Total rack surface area (m^2)	38,0 x 2,3 = 87,4	5,4 x 8,4 x 3 = 136,1	5,5 x 4,1 = 22,6	140,9	5,4 x 8,4 =45,4	24,0 x 5,5 = 132
normal water speed (m/s)	0,49	0,53	0,62	0,43	0,33	0,28
Escape openings	2	4	1	6	2	1
Dimension (h x w, in m)	0,65 x 0,30 0,20 x 0,20	0,57 x 0,25	0,30 x 0,50	Ø = 0,195	0,50 x 0,30	0,50 x 0,50
water flow (m^3/s; % of water)	0,60 (1,4 %)	1,5 (2 %)	0,15 (1,1%)	0,13 (0,2 %)	0,30 (2,0 %)	0,30 (0,8 %)
target species monitored**	silver eel, salmon smolt and	silver eel	trout smolt	silver eel	silver eel	salmon smolt
Estimated efficiency[3]	97-100%	>90%				
Estimated amount of outmigrated eel [4]	Ca 4000/year		-	-	-	-

** rack type defined as alfa means racks set at angel from bottom to surface vertically guiding fish uppwards before intake. Beta means racks set from bottom to surface horisontally angled to guide fish to either side of a plant away from intake*
***considering the design of installed grids, eel will also be able to pass the dam*

The costs

There are only a few attempts made to create a template for mitigation measures, and because of variations on each site and because some measures have been installed as part on routine maintenance it

[2] Based on and translated from report ”Fysiska avledare för uppsamling av blankål vid kraftverk” Energiforsk 2017:458
[3] Data from ”Tekniska lösningars tillämpbarhet för förbättrad nedströmspassage för ål” Elforsk 14:35, 2014
[4] Data from Calles et al 2012, ”Ål i Ätran - En fallstudie för svensk ålförvaltning” Karlstad Univ. Studies 2012:43

is difficult to assess. Depending on the required level of increased survival, costs are linked to both a one off cost (construction/installation) and a running cost (loss of water/production and keeping racks clean)

Costs on average for the plants in table 1 range from 40 000 Euros to 1,6 million Euros with an average cost around 470 000 Euros.

Larger plants

The same methodology has been investigated to put in use at also larger plants, for example at the power plant Älvås, in the river Motala ström just downstream the lakes Roxen and Boren on the Swedish Baltic east coast near the city of Norrköping. Installation of fine grid racks here would be larger as the plant is designed for intake capacity of 90m3/s. The rack would need to be an angled beta rack with a total size of 180 m2, to guide eels to the side of the plant. The construction would be designed to catch the eels for further transport to the sea since there are dams also downstream Älvås dam.

Estimated Construction costs *Total ca 2,4-2,8 million Euros*

- Building and installing the rack: ca 1,45 million Euros
- Unforeseen costs and project management: ca 600 000 Euros
- Eel collector device: ca 200 000 Euros
- Loss of production during Construction (1 year, 10 GWh/ productions 2-5 cent/kWh): ca 200 000-500 000 Euros

Estimated Running costs *Total of 47 000 – 53 000 Euros per year*

- Production losses
- Maintenance/cleaning
- Transport of eels

Very large plants

Calculations of also very large power plants have been made. In the major river system of Göta Älv on Swedish west coast, including the lake Vänern (largest in EU) the first power station is Vargön. With a total intake capacity of 930m3/s. The same type of sloped rack installation as above in this case would cost a total of 28-35 million Euros with a running cost of 300-400 000 Euros. In this particular case, the dam is the first after the large lake, but this is a drainage area today supported almost entirely by glass eel releases. If such releases were relocated, the measure would more or less be useless.

Making sure there is something to save

Since mitigations measures are both costly and takes time to reach the desired effect, it’s important to make sure the right rivers and sites are selected. Full effect of upstream and downstream measures cannot be fully seen until around 2030. Natural recruitment of eel is now very low in many waters and actual production upstream is not well known. There is therefore a risk that mitigation is done, based on assumptions of large upstream water bodies capacities, in rivers that simply do not produce eel of larger extent anymore. Both assuming a large upstream production and assuming hydropower kills eels up towards 100% will create an image of losses that perhaps don’t exist, or importantly the opposite, underestimation of river productivity results in incorrect prioritization of dams and rivers. Hydropower needs to cover their costs and pay for the damage done to the eel stock. However, we must make sure the expected result of those measures do not shift focus away from also other very direct mortalities.

Cost of stopping the fishery

The price of eel is high or very high today. The fishing has been reduced but yet there is still a substantial fishing on adult eels as well as juveniles. The high prices indicate the scarcity and subsequent increased prices. The marine catches of eel in the Baltic region alone is today (2017) around 385t, when adding the upstream catches and the recreational fishing it is a lot more and several times higher. Considering a commercial price of eel of around 10 Euros per kilo, the commercial fishery at first sale is worth ca 3,85 million Euros. This needs to be related to costs to increase survival at different kind of dams and hydropower stations. As noted above, installed mitigation at one mid sized plant is in total on average around 470 000 Euros. In one Swedish case (river Ätran) a well-made estimation shows that the mitigation may save at least 4000 eels per year, at cost of 117 Euros per eel.

A simplified calculation of what the commercial fishery current magnitude gives in first sale money terms:
385 000 kg of eel in Baltic Sea Region at 10 Euros/kg would equal 3,85 million Euros

Prices can be both lower and higher and if smoked and sold directly by fishermen its worth more than 10€ / kg.

Societies total costs for eel

Today the fishery is upheld to a great extent on relocating eels around EU. Incoming natural reproduction in the Baltic region is so low that without adding millions of juvenile eels the fishery would already be gone. Halting releases in areas and countries such as Belarus and Ukraine (connected to Baltic Sea via Vistula river in Poland) has made eels all but extinct, showing how poor natural recruitment really is. Eels above dams are mainly put there by humans, and in the Baltic regions this is the norm and not exception.

This setup means that first, society (and partly also fishing industry) pay fishermen a high price to catch juvenile glass eel and then we relocate the juvenile eels to our region. We even release them upstream dams. Then hydropower owners must pay for expensive mitigations measures in dams costing not only on-off installations but also yearly in maintenance and spill water lost to production. Finally, downstream in rivers or on the coast, eels are fished and the consumer pays again for the fresh or the smoked eel.

Concluding discussion

Mitigation for downstream migration in the form of sloping racks works, increasing survival to over 90% of eels attempting to pass. Costs vary but are medium to high and at larger dams very high. It is likely that effectiveness on total amount of saved eels per Euro would increase if several small to medium sized hydropower stations were addressed instead to very large ones. More saved eels for the same or even less money. However, proper investigations on actual river production, and not calculated or assumed, must be a key component to prioritise where to reach best results.

Large amounts of eel are released upstream dams that do not have mitigation measures for downstream migration installed. If such measures are indeed installed, in line with researched mitigation measures outlined in this paper, it really can increase the survival of eel. However, when we allow a commercial fishing downstream of such costly mitigation measures, it brings the actual kilo price on eel up to almost astronomical levels when including all costs. This is not well spent money and the eel stock is not recovering.