Maintaining and improving river connectivity with particular focus on impacts of hydropower

Report of a Theme-based Special Session of the Council of NASCO

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Main cover photograph of the Nedre Fiskumfoss, River Namsen, Norway. Courtesy of Eva Thorstad, NINA, Norway

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Executive Summary

NASCO's Theme-based Special Sessions are intended to facilitate a more detailed exchange of information on a specific topic relating to the Organization's agreements, drawing on the considerable range of expertise available during its Annual Meetings. In 2015, NASCO held a session on *'Maintaining and improving river connectivity with particular focus on impacts of hydropower'*. The objectives were to review and share best practice on the approaches taken by NASCO Parties and jurisdictions to:

- balance the pressures to refurbish existing and install new obstructions against the potential impacts on river connectivity, with particular reference to hydropower developments;
- mitigate the impacts of existing obstructions, including hydropower schemes, on salmon populations; and
- evaluate the benefits and costs of removing dams and other obstructions.

There were seven presentations during the session (Annexes 1 - 7) which provided examples of how obstructions are being dealt with in Canada, USA, Germany, England and Sweden, along with a perspective from the NGOs. In addition, all Parties/jurisdictions were asked to provide relevant information and the responses are contained in Annex 8.

Providing free passage for emigrating salmon smolts from their nursery grounds to the sea and for returning adult salmon to reach their spawning grounds might appear to be the most obvious requirement to support a healthy salmon stock. It is perhaps surprising, therefore, that so many countries around the North Atlantic have many thousands of obstructions on their rivers, varying from small culverts under roads to major hydroelectric dams, which restrict access to a large proportion of the catchment. Although there is usually a legal requirement to provide free passage for migratory fish past such obstructions, fish passes have often been poorly designed and largely ineffective. In addition, legislation has not always considered the importance of providing free passage for emigrating smolts in addition to returning adults, nor the more subtle effects such as delays to migration. The increased pressure on salmon stocks from reduced marine survival and other factors in fresh water, means it is now essential to optimise the natural production in fresh water and, therefore, to ensure that obstructions to river connectivity are minimised.

In many countries, salmon rivers have been used to harness hydroelectric power. There are also new drives to increase the proportion of energy generated by renewable sources leading, in some areas, to pressure to install new low-head facilities and giving rise to concerns particularly about cumulative impacts on migrating fish. In all cases it is important to evaluate the benefits of the scheme against the potential impacts and to ensure that impacts are minimised for any schemes that are approved. Furthermore, clear criteria should be set for approving all hydropower schemes.

There is a huge legacy of obstructions to tackle and a need, therefore, to prioritise the problems and seek the most cost-effective solutions. Where the use of obstructions is being reviewed or modified, the presumption should be that they should have minimal adverse effect on the fish population, and this means that all fish approaching the obstructions should be able to get past without delay. Modelling can assist in the assessment of impacts. The best option for mitigating the impact of an obstruction is to remove it completely. However, this is rarely straightforward. Several jurisdictions have, therefore, prioritised the potential management options along the following lines: remove the obstruction; build a natural fish pass (e.g. rock ramp or bypass channel); modify the obstruction or its operation (e.g. generating times) to improve fish passage; install a technical fish pass.

Opportunities to improve fish passage on some structures may come along infrequently, and so balance of a strategic approach and opportunism is needed in order to ensure that there is ‘no net loss’ of productive capacity in the salmon’s freshwater habitats. Partnerships can successfully raise awareness, provide funding and open doors to voluntary compliance.

Monitoring is an essential part of any mitigation programme and in recent years there appears to be greater emphasis on monitoring and evaluation of the effects of barriers, barrier removals and the efficacy of fish passage improvements. Ideally, baseline monitoring should be undertaken before any remedial actions are initiated to allow a complete assessment of any restoration outcomes after the project is implemented. Consideration should also be given to the indirect effects of barriers (e.g. on water quality, predation and disease transmission) which are not routinely captured and described in depth. Adaptive management is part of the process of barrier remediation in a number of jurisdictions.

Several countries have developed guidance documents relating to the management of obstructions. While these frequently apply to local situations and particular national legislation, there may be lessons for others to learn from such guidance and this might usefully be included on the NASCO website. Additionally, the findings of research into the impacts of river obstructions, including hydropower facilities, and the most effective mitigation methods should be disseminated widely, including through NASCO.

A fish pass in the River Langfjordelva, Finnmark, Norway. Courtesy of Eva Thorstad, NINA, Norway

Introduction

In 2013, the Council of NASCO had decided to change the structure of its meetings, initially on a trial basis, to allow for greater exchange of information through Theme-based Special Sessions. The first such one-day session was held in 2014 on the topic of *'Management of single and mixed stock fisheries, with particular focus on fisheries on stocks below their conservation limit'.* The report of that session is available from the Secretariat (document CNL(14)72). The Council of NASCO agreed to hold a second Theme-based Special Session at its Thirty-Second Annual Meeting (2015). The members of NASCO's Implementation Plan/Annual Progress Report Review Group (Paddy Gargan, Katrine Kaergaard, Paul Knight, Ted Potter, Rory Saunders and Sue Scott) were appointed as the Steering Committee to work with the Secretary to identify a topic, develop the objectives for the session and a Programme and prepare the report of the session.

Salmon habitat in freshwater has been greatly affected by various activities, both small- and large-scale in nature. It is clear that much habitat has been lost over the last 150 years, although in recent years there have also been some notable gains. NASCO's objectives of conserving, restoring and enhancing the Atlantic salmon can only be achieved if its habitat is protected, restored and, where appropriate, enhanced. Under the Plan of Action for Habitat Protection and Restoration, CNL(01)51, the goal for NASCO and its Parties is to maintain and, where possible, increase the current productive capacity of Atlantic salmon habitat. Barriers to migration in fresh water and estuaries, whether natural or man-made, can block or delay access and may lead to increased mortality through, for example, diseases, predation and, in the case of smolts and kelts, passage through turbines. Delays in smolt migration may also affect their survival when they enter the sea.

Several Parties and jurisdictions had presented information in their Implementation Plans and first Annual Progress Reports highlighting the threats and management challenges posed by obstructions, including hydropower facilities, to both upstream and downstream salmon migration. While progress in improving river connectivity is reported, including closure of some hydropower stations and dam removal projects, there are clear concerns about the increase in applications for 'run of the river' hydropower installations in salmon rivers in response to the need to meet renewable energy targets. The Steering Committee decided, therefore, that the topic for the

Theme-based Special Session should be *'Maintaining and improving river connectivity with particular focus on impacts of hydropower'.*

The Programme for the Theme-based Special Session is contained in document CNL(15)14. In addition to the contributed papers that are annexed to this report, additional contributions were received from the European Union (*LIFE and freshwater fish*, CNL(15)50), European Union - Finland (*Fish Passage Strategy - Towards a natural life cycle,* CNL(15)49) and the Russian Federation (*Transferring Atlantic salmon above a hydropower dam in the Kola Peninsula, Russia,* CNL(15)46). These documents are available at www.nasco.int/2015councildocs.html.

Unkelmühle dam and fish pass. Courtesy of Klaus Göhring.

Objectives

The objectives of the Theme-based Special Session were to review and share best practice on the approaches taken by NASCO Parties and jurisdictions to:

- balance the pressures to refurbish existing and install new obstructions against the potential impacts on river connectivity, with particular reference to hydropower developments;
- mitigate the impacts of existing obstructions, including hydropower schemes, on salmon populations;
- evaluate the benefits and costs of removing dams and other obstructions.

The Steering Committee had requested that presentations:

- describe arrangements in place for consultation and information exchange among relevant agencies and stakeholders in relation to hydropower developments;
- indicate, briefly, work underway to improve the evidence base relating to fish passage;
- describe how conservation of productive capacity is taken into account in evaluating options for hydropower developments;
- where hydropower developments are approved, on the basis of overriding socio-economic factors, describe how any losses of productive capacity are minimised and compensation or mitigation measures agreed so that there is no net loss of productive capacity; and
- highlight any examples of initiatives to improve fish passage, with particular reference to hydropower developments, which involve collaboration between governments and other stakeholders.

As it was not feasible to have presentations from all Parties/jurisdictions in a half-day session, the Steering Committee had requested that all Parties and jurisdictions provide written responses to the five bulleted points above. These written responses are included in Annex 8 of this report. In developing its conclusions the Steering Committee has drawn on the contributed presentations, the discussions and the responses from Parties/jurisdictions to the issues raised by the Steering Committee.

Opening Remarks by the Vice-President of NASCO

The Vice-President, Mr Jóannes Hansen, opened the Theme-based Special Session. He indicated that there had been very positive feedback from the 2014 session on the management of fisheries and the resulting publication had been widely circulated. He noted that the intention of such sessions is to allow for an open and detailed exchange of information on a particular topic drawing on the wide range of experience and expertise that assembles for NASCO meetings. Habitat loss, due to its destruction, degradation or fragmentation, is a major threat to wildlife around the globe and the salmon is no exception. The focus for the session was river connectivity and the impacts of hydroelectric developments. Dams are some of the most dramatic and visible alterations to the salmon's environment but other impacts on river connectivity may be less apparent, as would be highlighted in the presentations. He stressed that Atlantic salmon can only thrive if smolts leaving their natal rivers have free passage to the ocean and returning adults can reach their spawning grounds. It is clear from the Annual Progress Reports to NASCO that there are concerns about an increasing number of applications for 'run of the river' hydropower schemes in salmon rivers, but also that there has been some real progress in improving fish passage including some very high profile dam removal projects, such as the removal of the Veazie Dam on the Penobscot River. It is also clear from many examples that where habitat has been improved, the salmon can respond despite the current period of low marine survival.

He thanked the Steering Committee and the Secretary for the planning that had gone into organising this session. He also encouraged all participants to contribute to the session, from which one of the outputs should be a clearer understanding of best practice in mitigating impacts of hydroelectric developments.

Summary of Contributed Papers

Efforts to improve river connectivity in Canadian waters, CNL(15)57 (Annex 1)

Significant challenges remain to remediate the numerous barriers existing in eastern Canada that present a problem to the natural migration of Atlantic salmon. Efforts have been made in recent years to address these challenges through partnerships, research and funding efforts. The work of governments, aboriginal organisations, non-governmental organisations/recreational fishing groups and the public in general is slowly improving the ability of fish to migrate and access habitat. Despite this, new challenges present themselves in the form of changing climate and additional land-use pressures that will need to be addressed through a combination of integrated planning, research, aboriginal traditional knowledge and furthering partnerships with concerned groups and individuals.

Partnerships will be key to addressing barriers to migration going forward. One example of this collaboration occurs between Fisheries and Oceans Canada and Provincial departments to improve fish passage at existing structures. As old structures are being replaced, as in the case of culverts, they are being upgraded to the most recent specifications for fish passage. Additionally, agreements with partners for construction of fishways through and around existing dams and for dam removal are being developed and/or considered. Continuous efforts are undertaken through those partnerships to address fish passage issues. Where mandatory offsetting plans are deemed necessary to compensate for habitat loss, proponents are strongly encouraged to reopen watersheds by removing old structures (e.g. abandoned dams) or improving fish passage (e.g. hung culverts). Even though an exact number is hard to define, many thousands of square kilometres of catchment have been reopened to fish migration in eastern Canada over the last few years.

Notwithstanding the fact that fish passage is a legal requirement under the Federal Fisheries Act, it is considered that impediments to fish passage dealt with through partnerships and agreements raise a greater level of awareness and open doors to voluntary compliance.

The Penobscot River Restoration Project - A multi-stakeholder effort to significantly improve access to historic habitat for Atlantic salmon and other sea-run fish, CNL(15)45 (Annex 2)

The Penobscot River is the largest river system in the State of Maine and its run of approximately 1,000 Atlantic salmon (ten year average) is by far the largest remaining in the USA. For two centuries, the cumulative impacts of dams have caused widespread harm to people and wildlife in the Penobscot catchment. A report prepared in 2004 by the National Academy of Sciences affirmed that there are too many dams on the Penobscot River for successful salmon restoration, and that many other species would also benefit from dam removals. The report recommended a ‘primary focus’ on the Penobscot River and ‘a program of dam removal, with priority on those dams whose removal would make the greatest amount of spawning and rearing habitat available'. The Penobscot River Restoration Project ('the Penobscot Project') addresses this recommendation. In June 2004, the Penobscot River Restoration Trust signed the Lower Penobscot River Multi-Party Settlement Agreement ('the Agreement'), a collaborative, far-reaching blueprint for a win-win, public-private effort to rebalance hydropower and sea-run fisheries on the Penobscot River. The benefits of the project are expected to include: providing unobstructed access to 100% of historic habitat for 'lower river' species such as Atlantic and shortnose sturgeon and striped bass; significantly improved access to nearly 1,000 miles of historic river habitat for endangered Atlantic salmon and other 'upper river' species of native sea-run fish; restoration of critical ecological functions that will benefit native plant and animal communities in the river, estuary and Gulf of Maine; maintenance of hydropower generation; and revitalisation of the Penobscot Indian Nation's culture and traditions. To date, the Penobscot Trust, working with its many public and private partners, has removed the two lowermost dams. The Great Works Dam was decommissioned and removed in 2012 and the Veazie Dam was decommissioned and removed in 2013. A recently constructed fish lift at the Milford Dam, above the reconnected lower river, now allows fish to pass another 40 miles to Howland. However, the Howland Dam still blocks access to high quality spawning, nursery and rearing headwater habitat. This dam has been particularly harmful to young salmon, typically killing 23% of the salmon smolts migrating to sea each spring. The project is now focused on the construction of a natural fish bypass around the decommissioned Howland Dam which is scheduled for completion during 2015.

Monitoring of the Penobscot Project was initiated in 2009 using a multidisciplinary, before and after approach. This baseline monitoring has provided a snapshot of pre-dam removal conditions and thus an objective basis for evaluating restoration outcomes post project implementation.

Restoration of upstream and downstream connectivity on the River Rhine, CNL(15)42 (Annex 3)

Catches of salmon in the River Rhine peaked at 250,000 fish in 1885, but subsequently declined due to the construction of obstacles to migration and, to a lesser extent, deterioration in water quality and overexploitation. By the late 1950s, Atlantic salmon had been lost from the Rhine. Following the 'Sandoz disaster' in 1986, a major pollution incident in the main stem of the Rhine, a restoration programme commenced and since 1990 salmon have been recorded in increasing numbers in the river. One of the main issues for the International Commission for the Protection of the Rhine (ICPR) is the restoration of river connectivity for which the Atlantic salmon has become a key species. At the 2013 Conference of Rhine Ministers important steps were agreed to improve river connectivity in support of the objectives of the programme 'Rhine 2020' (establishing general objectives for the protection of the Rhine and the measures required for their implementation) and the 'Master Plan Migratory Fish Rhine' (aimed at restoring self-sustaining, stable populations of migratory fish in the Rhine catchment as far as the Basel area).

There are more than 1,200 hectares of salmon habitat in the Rhine catchment and by 2012 about one fifth was accessible. Important habitat in the Upper Rhine (upstream of Strasbourg) and in the Moselle (the second largest tributary) remains inaccessible to salmon and a future challenge is to address this issue. By 2013, almost 500 barrage weirs had been made passable either by installing fish passes or by removal of the obstruction. In 2018, the Haringvliet sluices in the Netherlands, at the main entrance from the sea of the Rhine and Meuse rivers, will be partially opened in order to facilitate upstream migration of fish (currently the sluices only permit downstream passage). In the Upper Rhine, five dams still require installation of fish passes to allow access to Basel, but in 2015 the fish pass at the Strasbourg dam will be operational and construction work will commence at the Gerstheim dam.

Lessons learned from assessment of the effectiveness of existing passes is being used to inform future installations. Damage to fish migrating downstream through turbines is cumulative and in the Rhine and its tributaries, where there are numerous hydropower plants, this mortality is considered to pose a threat to the stock rebuilding programme. A return rate of at least 1% of downstream migrating smolts is considered necessary to build a self-sustaining population but the goal is to achieve a higher return rate than this. The ICPR has identified 552 bottlenecks to downstream migrating smolts and few of these have facilities in place to prevent passage through the turbines. Migrating fish can be damaged by the turbine blades or guiding vanes, by differences in pressure, and by high flow rates and turbulence. Additionally, there may be indirect effects such as increased predation of smolts that are delayed in their migration or disoriented by passage through the turbines. The Kaplan turbine is the predominant type in use in the main stem of the Rhine; the mortality rate of fish passing through these turbines (<5% - ~20%) is lower than for the Francis turbine (<5% - >90%). Some of the smaller, recently constructed hydropower stations use the Archimedes screw and studies have indicated mortality rates from 0 - 5% of fish passing through these. Recent studies in the Rhine have focused on best practice solutions to prevent fish passing through the turbines with the first results expected in 2016.

While much has been achieved to restore connectivity in the Rhine, the issue remains the biggest challenge to the restoration and protection of migratory fish species in this river.

Maintaining and improving river connectivity: the current position and experience in England, CNL(15)43 (Annex 4)

The Environment Agency has established a geographic database of obstructions across England and Wales. It identified 26,000 obstructions of a range of sizes (18,000 of which are man-made) on a river network length of 300,000km. The database allows for a much more systematic approach to improving river connectivity and integrating this information into river basin planning. In the most recent assessment of reasons for not achieving 'Good Ecological Status' under the Water Framework Directive, physical modifications including obstructions were identified as the most significant factor. Through cooperative initiatives more than £22million was invested between 2009 and 2014 in addressing 229 obstructions across England and Wales. The Environment Agency follows a hierarchy in decision-making in relation to river connectivity: remove the obstruction > construct a natural bypass > modify the obstruction to make it passable > install a fish pass. For England's 42 principal salmon rivers, 63 fish passes and easements were built between 2009 and 2014, which have improved access to 3,700km of river (equivalent to the distance from London to the west coast of Greenland). Eight of these 63 fish passes and easements were linked to hydropower schemes.

In 2009, the UK signed up to a legal obligation to meet 15% of its energy demand from renewable sources by 2020 and hydropower is seen as having the potential to make a small but useful contribution to this target. The Environment Agency receives about 30 - 40 applications for new hydropower developments each year. In determining permits, the Environment Agency is required to address impacts on: water flow and availability and other permitted water users; fish and fisheries; protected wildlife and habitats; and the management of flood risk. Guidance has been developed in consultation with the hydropower industry and fisheries interest groups. On a number of rivers, hydropower developments have been accompanied by new fish passes that have improved the migration pathways for salmon and other fish. To protect flows and maintain and improve river connectivity, four tests have been developed to ensure that hydropower developments do not have unacceptable impacts. Hydropower developments: must not prevent the achievement of Water Framework Directive (WFD) objectives at water body level; must not have unacceptable impacts on protected sites or species; must not have unacceptable impacts on the rights of other water users; and must maintain or improve fish passage and fisheries. On a number of rivers, hydropower developments have been accompanied by new fish passes that have improved the migration pathways for salmon and other fish. Modelling of the effects of multiple developments indicated a range of effects from +18% to -12% on the numbers of returning adult salmon expected. The study found that the variation in effect was highly dependent on the assumed passability of existing barriers, the efficiency of any constructed fish pass, and the location of the scheme on the river with downstream-sited schemes having the potential to cause larger positive or negative effects. Positive effects were always driven by the inclusion of improved fish passage at individual schemes.

The Environment Agency and Cefas are working with the Game and Wildlife Conservation Trust to investigate the effect of a small low-head hydropower scheme on the behaviour of emigrating wild salmon and sea trout smolts on the River Frome in Dorset. Maintaining and improving river connectivity is a critical issue to safeguard England's salmon populations. On England's principal salmon rivers, the Environment Agency has identified 72 super critical and high priority obstructions which, when addressed, would open up access to a significant amount of river habitat, providing the potential for a substantial increase in smolt output.

Progress in developing best available technology for hydropower generation and other initiatives to improve fish passage in Sweden, CNL(15)41 (Annex 5)

In Sweden, 2,100 hydroelectric power stations generate 40% of the total electricity produced. The largest 206 hydropower stations, mainly in the north, account for 93% of the country's total hydropower production. Prior to the 1960s, little consideration was given to environmental issues when considering hydropower developments but, in 1983, new legislation was enacted which made it more difficult to obtain permission to build new hydropower plants. This new legislation gave the environmental courts additional powers to specify conditions for hydropower generation that took greater account of the environment. In 2014, a new environmental law, more consistent with the EU Water Framework Directive, was developed that proposed that permits for hydropower plants should be time limited, that the environmental authorities should be able to decide on new terms for the hydropower plants in the same way as for other environmentally damaging industries and that the hydropower plants should bear their own costs for measures to protect the environment. The Government has not yet decided whether or not to present this legislation to the Swedish Parliament.

In 2012, the Swedish Agency for Marine and Water Management was given a government mandate to initiate a dialogue with the relevant authorities and other stakeholders with the aim of building increased consensus on hydropower, taking account of EU objectives for renewable energy and the environment (biodiversity and water management). Outcomes from this dialogue have been a consensus on the river systems in which hydropower production is most important and acknowledgement that the ~1,900 smaller hydropower plants, which produce only 7% of the total hydropower production, have a major impact on biodiversity that could easily be addressed.

Both upstream and downstream fish passage can be improved in four ways: removal of hydropower plants, dams and reservoirs; opening of dam or sluice gates; installation of natural fishways; and installation of technical fishways. In the last twenty years, a number of small, old hydropower plants producing little electricity and old plants requiring costly renovation have been removed from Atlantic salmon rivers in Sweden. Dam removal can be less costly than installing a fishway and means that habitat lost to salmon production may become available and delays to migrating smolts, which can result in increased predation, are avoided. A considerable difficulty in removing dams can be the high sediment load from the old impoundment and issues with the stability of the ground particularly where there are buildings near the dam. One possible solution is to retain the dam and open the sluice gates during peak migration periods to facilitate migration of salmon without passage through the turbines.

Establishing Best Available Technology is a joint project involving the Swedish Agency for Marine and Water Management, the hydropower industry, County boards and Universities. The recommendation is that fishways at artificial dams should allow migration of all species and age groups of fish. Nature-like fishways are preferred (e.g. bypass, rocky ramp, fish slope, bypass through the dam) and a maximum slope of 5% is recommended unless passage would be difficult for species other than salmon, in which case a technical fishway may be installed. For technical fishways, the vertical slot design is preferred over pool and weir fishways, which again are preferred to the Denil pass. The design of technical fishways should also allow species with weaker swimming ability to pass. The depth in technical fishways should be at least 1m with a flow of $1m^3/s$ for salmon and large sea trout and a depth of 0.5m and flow of $0.5m^3/s$ for smaller sea trout and other species. The attraction flow should be 5% of the flow at the site and the fishway entrance should be in a suitable location. Sluices and elevators are not recommended. Fish larger than 10cm (smolts) should always be screened away from the turbines. Physical screens are preferred to behavioural techniques (electricity, sound, light, bubbles etc.). Beta-screens (angled across the river usually at 30^o) are preferred to alpha-screens (angled vertically but aligned perpendicular to the flow) and the least preferred solution is other types of screens (e.g. louvre). Screens should be installed from the surface all the way to the bottom with 10 - 18cm spacing between the bars. The flow in the fishway should be at least 2% of the flow at the site. Automatic regulation of flow at dams is preferred, allowing for better monitoring and less pronounced alterations in flow. The outlets from power plants and dams should allow bottom and surface water of different proportions to be used in order to avoid high temperatures and facilitate sediment transport. Safety installations are required to avoid loss of water in the river bed due to technical failures.

Measures to improve fish passage in the north-eastern United States including development of performance (survival) standards for fish passage at hydro-electric dams, CNL(15)44 (Annex 6)

The primary objective for the management of Atlantic salmon in the United States is to rebuild the Gulf of Maine Distinct Population Segment (GOM DPS) and the ecosystems upon which salmon depend to a point where the protections of the Endangered Species Act are no longer required. The primary threats to endangered Atlantic salmon are low marine survival and dams and an enhanced strategy to restore connectivity within the freshwater range of the GOM DPS is under way.

No new mainstem dams have been constructed in Maine since 1989.

As licences for existing dams typically expire every 30 years, the dam owners must consult with the Federal Energy Regulatory Commission (and consequently NMFS and USFWS) to obtain a new licence. These events are opportunities to improve fish passage in most instances. In the past, NMFS and USFWS provided dam owners with design criteria for the construction of fishways. If the fishways ultimately proved to be ineffective at passing fish, there was little recourse available to the agencies. Recently, NMFS has moved away from designing fish passage devices and has focused instead on performance criteria that must be achieved to ensure the survival and recovery of the species. This novel approach includes the development of performance (survival) standards at each hydroelectric dam within the freshwater range of the GOM DPS. NMFS also requires that the dam owners monitor whether they are attaining the necessary survival standards, and if the rates are not achieved, take action to improve passage performance and to ensure that the standards are met. Further, the dam owners must demonstrate, through quantitative monitoring, that they are meeting or exceeding the performance standard for at least three consecutive years in order to continue to operate the dam.

A Dam Impact Analysis (DIA) Model has been developed to evaluate upstream and downstream survival standards at hydroelectric dams and ensure that recovery of Atlantic salmon can be achieved. The first application of the DIA model was in the Penobscot River. In 2011, a Species Protection Plan was developed by the owners of the four dams (Milford, Stillwater, Orono and West Enfield) on the lower Penobscot River that proposed continued operation of the dams with several stringent conservation measures that should result in high levels of downstream smolt survival (96% within 24 hours) and high levels of upstream passage for adults (95% within 48 hours). Given the various conservation measures outlined in the Species Protection Plan, it was determined that the continued operations of these four dams would not preclude recovery of Atlantic salmon as long as certain mitigating activities were undertaken including: the removal of the Veazie and Great Works Dams (the two lowermost mainstem dams on the river); immediate decommissioning of Howland Dam and the installation of a bypass structure around the dam; immediate attainment of downstream survival levels of 96% at the remaining four mainstem dams and immediate attainment of upstream passage rates of 95% at Milford and West Enfield dams; sustained improvements in freshwater and marine survival; and continued supplementation by Green Lake National Fish Hatchery.

The DIA Model can be used to compare alternative scenarios of environmental and dam conditions to identify critical parameters and information needs for recovery efforts. If a dam appreciably reduces the species' chances of survival and recovery, an alternative must be developed (e.g. new fishway, turbine shutdowns and spillage, downstream diversion) that would improve the abundance, distribution or reproduction of Atlantic salmon in the geographic area impacted by the dam. By requiring the dam owners to meet certain and explicit upstream and downstream survival standards, there is a clear assurance that the project will have minimal impacts on the survival and recovery of Atlantic salmon. These assurances can only be delivered when accompanied by a rigorous monitoring and review process. In short, this process uses an adaptive management approach to articulate a goal (the performance standard), quantitatively monitor whether or not the goal is attained, review results and adjust as necessary.

The Penobscot, Kennebec, and Androscoggin Rivers contain a significant amount of valuable habitat for Atlantic salmon in Maine as well as a number of hydroelectric dams. In future, the DIA Model will be used to identify survival standards at all dams in the GOM DPS necessary to protect and recover Atlantic salmon.

Maintaining and improving river connectivity with particular focus on impacts of hydropower - an NGO perspective, CNL(15)48 (Annex 7)

Although the focus of the Theme-based Special Session was on impacts of hydropower, this presentation considered the wider perspective of river connectivity affecting the free passage of Atlantic salmon, from headwater spawning and juvenile habitat down to the ocean and back. For salmon to survive and prosper, there must be river connectivity and free passage so that the fish can access both their freshwater and marine habitats with as little delay or impact from human interference as possible. While hydropower can have a significant impact on migrating fish, other factors affecting migration need to be considered at a catchment level. Downstream migration of salmon does not always receive the same attention as the return adult migration, but dams and weirs can delay smolts and make them more vulnerable to predation, with cumulative effects where there are multiple barriers. Access to spawning grounds requires efficient fish passes at a range of potential barriers to migration (including tidal barrages, weirs and hydropower plants) with sufficient flow provided to attract migrating fish at all river levels. Looking at other factors affecting river connectivity, activities such as excessive water abstraction, dredging of gravel or poor land management practices can adversely affect spawning and juvenile habitat. Such habitat is often located in upland areas. Freshwater salmonid farming can impact water quality through discharge of nutrients, such as phosphorus, and contaminating chemicals including endocrine disruptors. Sea lice and diseases emanating from salmon farms located in marine waters can cause significant mortality as smolts make the transition from fresh to sea water. The NGOs believe that closed containment is the only way to minimise impacts of aquaculture on wild salmon. For returning adult fish, tidal barrages and low flow conditions, due to droughts or excessive abstraction, may delay river entry and result in increased predation. Low flows into estuaries are often overlooked in water resource plans as many fail to recognise fisheries issues. Both netting and rod fisheries can cause a significant loss of returning fish and, if there is no harvestable surplus, netting should cease and rod fishing should be subject to catch and release. The NGOs consider that coastal mixed-stock fisheries should be closed as they are indiscriminate. At the 2011 NASCO/ICES Salmon Summit it was recognised that the goal for salmon managers should be to produce the maximum number of healthy, wild smolts and this objective will only be achieved if spawning and juvenile habitats are protected and river connectivity maintained and improved and there is a strong political commitment to safeguard the salmon and its habitats in the face of competing demands for economic development and growth. Healthy rivers and water quality benefit local communities and economies as well as salmon.

Concluding remarks by the Chairman of the Steering Committee

In summing-up the session, the Chairman of the Steering Committee, Mr Ted Potter, noted that although the importance of maintaining upstream passage to the salmon’s spawning grounds has been known for many years, the impacts of even relatively modest obstructions, such as culverts, were often underestimated, and the effectiveness of fishways was often over-estimated. Furthermore, recognition of the importance of providing safe downstream passage for smolts and of the broader ecosystem importance of river connectivity is more recent.

The impact of river obstruction is also often exacerbated by the addition of hydropower generation which may cause both direct mortalities (e.g. due to impacts of turbine blades) and indirect losses (e.g. due to increased predation on fish held up in the impoundment). Many hydropower stations are now old and in need of refurbishment, and this provides opportunities to improve fish passage either by modifying mitigation measures or removing the dams completely. However, in some countries there is increased interest in hydropower in order to meet targets for renewable energy generation, so while some hydropower facilities are being removed, others are being built. A major challenge is therefore to ensure that the benefits of hydropower can be realised without adverse effects on salmon and other migratory fish through the installation of efficient fishways, including downstream migration facilities that bypass the turbines.

The presentations during the Theme-based Special Session highlighted the very large number of dams and weirs that exist on salmon rivers in most jurisdictions, and it is clear that addressing all fish passage issues will require major programmes and substantial expense. There is a need, therefore, to assess these obstructions and identify those where remedial action will provide best value for money. Several approaches for evaluating and prioritising obstructions were presented, including population modelling and developing impact matrices, but it was also noted that it may not be possible to implement the most desirable mitigation options for salmon due to costs or other pressures. It was suggested that, in general terms, options for addressing obstructions may be prioritised as: removal of the obstruction; construction of a natural bypass channel; modification of the obstruction to reduce its impact; and installation of a fishway.

Several speakers had emphasised the importance of implementing both before and after monitoring (e.g. physical and geomorphic, water quality; fish passage, fish communities, ecosystem function and fish habitat use) to evaluate the effectiveness of measures implemented to improve river connectivity. Where anticipated benefits are not being realised, an adaptive management approach should be adopted. Speakers had described new approaches for assessing the effectiveness of fish passage including performance criteria (survival standards) to ensure the survival and rebuilding of fish populations.

While the costs of improving fish passage are often high, the benefits to the salmon and other species (such as eel, sea trout, shad, lampreys and river herring) can be great. Solutions should therefore be sought that take account of the wider ecological benefits of river connectivity, thereby benefiting multiple species, and address multiple legislative drivers. The presentations had demonstrated the benefits of sharing experiences among NASCO Parties and jurisdictions. A number of guidance documents had been described, and it would be helpful if these were made more widely available. The Theme-based Special Session had allowed for an excellent exchange of information and useful discussions, and thanks were due to all participants and particularly to the presenters.

Conclusions of the Steering Committee

Providing free passage for emigrating salmon smolts from their nursery grounds to the sea and for returning adult salmon to reach their spawning grounds might appear to be the most obvious requirement to support a healthy salmon stock. It is perhaps surprising, therefore, that so many countries around the North Atlantic have many thousands of obstructions on their rivers, varying from small culverts under roads to major hydroelectric dams, which restrict access to a large proportion of the catchment. In some cases these constructions date back many centuries, but the majority were built during the industrial revolution in the 19th century and with the expansion of road networks and electricity generation in the 20th century. At that time, the focus of such developments was on facilitating industrial development and improving communications and standards of living, and this generally took precedence over conservation of the natural resources of the river.

Although there has frequently been a legal requirement to provide free passage for migratory fish past such obstructions, usually by installing a fish pass, these structures have often been poorly designed and largely ineffective. In addition, legislation has not always considered the importance of providing free passage for emigrating smolts in addition to returning adults, nor more subtle effects such as delays to migration. In the past, many stocks were able to tolerate the impact of obstructions, but as a result of the increased pressure on salmon stocks from reduced marine survival and other factors in fresh water, it is now essential to optimise the natural production in fresh water and, therefore, to ensure that obstructions to river connectivity are minimised. Despite the many new problems facing salmon today, including climate change and increasing demands for water, connectivity is the greatest challenge for the restoration and protection of migratory fish species on many rivers. It is, therefore, essential that every effort be made to ensure that salmon can access as much suitable habitat as possible.

Hydropower

In many countries, salmon rivers have been used to harness hydroelectric power and in Sweden, for example, 2,100 hydropower stations generate 40% of the total electricity produced. There are also new drives to increase the proportion of energy generated by renewable sources in response to growing concerns about climate change. In some areas, this is leading to pressures to install new low-head facilities on existing, and even new, weirs and dams, often using Archimedes screw turbines. While these turbines are generally thought to be much less damaging to migrating fish than traditional high-head turbine designs (e.g. Kaplan turbines), the technology is still relatively new and so the potential impacts are uncertain. In addition, there are concerns about the possible cumulative effects of multiple hydropower facilities being developed on some rivers, even if the impacts of the individual schemes are relatively small. For older hydropower stations, the requirement to replace equipment or renew operating licences may provide the opportunity to reduce their impact by modifying facilities or removing them completely, but such opportunities may arise very infrequently. In all cases it is important to evaluate the benefits of the scheme against the potential impacts and to ensure that impacts are minimised for any schemes that are approved. Furthermore clear criteria should be set for approving all hydropower schemes.

Prioritising actions

There is a huge legacy of obstructions to tackle, and the examples of mitigation programmes provided to the Theme-based Special Session clearly showed that the cost of rectifying these will be very substantial. For example, by 2013 almost 500 barrage weirs had been made passable on the River Rhine system in Germany, either by installing fish passes or by removal of the obstruction. There is therefore a need to prioritise the problems and seek the most cost-effective solutions as there are simply too many barriers to address all at once in some jurisdictions.

In England and Wales there are over 18,000 man-made obstructions on rivers, and so a matrix approach has been used to identify high priority obstructions where the greatest benefits will be seen for multiple species (salmonids, coarse fish and eels). The Environment Agency has identified 72 ‘super critical and high priority’ obstructions which, when addressed, would open up access to a significant amount of river habitat, providing the potential for a substantial increase in smolt output. This process will also take account of the views of local stakeholders as part of a process of updating Sea Trout and Salmon Catchment Summaries.

Where the use of obstructions is being reviewed or modified, the presumption should be that they should have minimal adverse effect on the fish population, meaning that all fish approaching the obstructions should be able to get past without delay. Modelling should be used to assess the likely impacts of obstructions, both with and without hydropower facilities, as has been demonstrated in relation to the renewal of hydropower licences on the Penobscot River, USA, and to evaluate the possible impacts of new hydropower facilities in England.

It was also noted that fishways are never 100% effective even for the species they are designed for, and weak-swimming fish may find even the most well-designed fishways insurmountable. It was, therefore, accepted that the best option for mitigating the impact of an obstruction is to remove it completely. However, this is rarely straightforward. It may be possible for old weirs and dams which are no longer required for their original purpose, but where weirs have been in place for many years, the management of the local reaches of the river will have been modified to accommodate them, and their removal may have implications for such uses as navigation and recreation. Furthermore, where the obstruction is still used, e.g. to generate power or provide an abstraction point, removal may not be possible.

Technical fish passes, such as pool and weir systems, are now regarded as some of the less passable fishways, particularly for weak-swimming fish. Thus, there has been a marked shift towards building more natural fishways in the form of rock ramps or bypass channels. These are not only more effective for salmonids but can frequently be used by a wide range of other fish species and invertebrates.

Several jurisdictions have, therefore, prioritised the potential management options along the following lines:

1. Remove the obstruction;
2. Build a natural fish pass (e.g. rock ramp or bypass channel);
3. Modify the obstruction or its operation (e.g. generating times) to improve fish passage;

4. Install a technical fish pass.

Opportunities to improve fish passage may come along infrequently since they may be tied to funding availability, licensing (or re-licensing) that may only occur once in a few decades, or legislative or judicial decisions that may take years before decisions are reached. Thus, it seems clear that a balance of a strategic approach and opportunism is needed if we are to ensure that there is 'no net loss' of productive capacity in the salmon's freshwater habitats across the north Atlantic, in accordance with NASCO guidance.

Partnerships

Several countries indicated at the Theme-based Special Session that bringing together like-minded partners and their resources has been key to addressing barriers to fish migration, and a number of examples are described in Annex 8, Section 5 of this report. Notwithstanding that fish passage is generally a legal requirement, dealing with obstructions through shared stewardship and partnerships raises a greater level of awareness, provides funding and opens doors to voluntary compliance. On the Penobscot River, for example, the Penobscot Trust working with hydropower companies, seven conservation groups and federal, state, and tribal governments has already removed the two lowermost dams on the river and (at the time of writing this report) is completing the nature-like bypass of the third upstream dam. In England, the evaluation of obstructions will be complemented by 'crowd sourcing' data through a phone-based app that will enable people to provide information in a way that links to a geographic database.

Monitoring and maintenance

Monitoring was also highlighted as an essential part of any mitigation programme and in recent years there appears to be greater emphasis on monitoring and evaluation of the effects of barriers, barrier removals and the efficacy of fish passage improvements. Too often in the past, new fish passes were installed but no monitoring was undertaken to check that they were working. Where feasible it should be the responsibility of the operator to demonstrate that the obstruction and fish passage facilities meet predetermined survival standards for the proportion of fish that get past within an acceptable time. Ideally, baseline monitoring should be undertaken before any remedial actions are initiated to allow a complete assessment of any restoration outcomes after the project is implemented. Consideration should also be given to the indirect effects of barriers, for example on water quality, predation and disease transmission, which are not routinely captured and described in depth. Ideally monitoring might take account of the following parameters, as has been applied on the Penobscot River:

- physical and geomorphic;
- water quality (chemical and benthic invertebrates);
- wetland and riparian community (including invasive species monitoring);
- fish passage (up and downstream via tagging and hydro-acoustic methods);
- fish community (presence and abundance);
- reproduction and habitat use of threatened and endangered species (including habitat suitability modelling and active tagging); and
- ecosystem function (marine derived nutrients).

Adaptive management appears to be part of the process of barrier remediation in a number of jurisdictions. This is an encouraging development as implementing the full process of adaptive management offers considerable hope of expediting the delivery of the most effective conservation strategies through 'learning by doing'. The standard model of adaptive management is a multi-step process. One key part of the process is development of performance metrics. In aquatic conservation strategies, the development of these performance metrics can be challenging, particularly in light of the uncertainty associated with measuring them. Although many jurisdictions indicated that the adaptive management model was now being used, precise definitions of performance metrics were rarely reported. Further information sharing along these lines would seemingly be a welcome development.

Guidance documents

The main objective of the Theme-based Special Session was to review and share best practice on the approaches taken by NASCO Parties and jurisdictions to tackle river connectivity problems. Several countries have developed guidance documents relating to the management of obstructions, a number of which were referred to during the Theme-based Special Session and elsewhere in this report, including:

- Sweden - Best Available Technologies: Annex 5 of this report provides an update on Sweden's progress and, when complete in Autumn of 2016, all documents will be available online and in English at: https://www.havochvatten.se/4.3840a1fa147f96ca771cfed1.html
- United States - Stream Barrier Removal Monitoring Guide: http://www.gulfofmaine.org/streambarrierremoval/
- England and Wales - River Restoration Manual: http://www.therrc.co.uk/manual-river-restoration-techniques
- Ireland - Fisheries Guidelines and Best Practice for Planning, Design, Construction & Operation of Hydro-Electric Schemes: http://www.fisheriesireland.ie/Fisheries-management/fisheries-management.html

While these frequently apply to local situations and particular national legislation, there are frequently lessons for others to learn. Although NASCO is not able to endorse the content of these or other such documents, we nevertheless recommend that Parties and jurisdictions make any such guidance available through the NASCO website where they can be shared by all Parties. In addition, a wide range of research is being undertaken to improve our understanding of the impacts of river obstructions, including hydropower facilities, and the most effective methods for mitigating their impacts and every effort should be made to disseminate the results of this work widely, including through NASCO e.g. in the Annual Progress Reports on Implementation Plans prepared by each NASCO Party/jurisdiction.

Annexes

Annex 1

CNL(15)57

Efforts to improve river connectivity in Canadian waters

Introduction

Atlantic salmon are broadly distributed along Canada's east coast and historically occurred in hundreds of rivers including a population in Lake Ontario. The current number of Atlantic salmon rivers is approximately 937 although a component of these have "unknown" status (http://www.nasco.int/RiversDatabase.aspx). In Canada salmon populations have been in decline, the most severe of which have occurred in the 32 rivers of the inner Bay of Fundy, where Atlantic salmon have been designated as "endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and listed under Canada's Species at Risk Act (SARA) (http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=672). Numerous rivers in the Southern Upland of the Atlantic coast of Nova Scotia are either threatened with extirpation or have already been extirpated (DFO, 2009).

Aquatic habitats and their adjacent terrestrial areas are valued for a wide range of human uses. The integrity of salmon habitat is challenged by human demand for accessible land and fresh water, for ocean spaces, and for the interconnecting estuarine and coastal areas. In both freshwater and estuaries and near-shore marine areas, human activities can affect the biological, physical, and chemical components of salmon habitat resulting in adverse impacts during critical spawning, rearing, and migration periods. In the open ocean, activities such as commercial fishing, shipping, and waste disposal among others can potentially affect the marine habitat of salmon (DFO, 2009).

This paper supports a presentation made by Canada during the Theme-based Special Session on 'Maintaining and improving river connectivity with particular focus on the impacts of hydropower', at the North Atlantic Salmon Conservation Organization's 2015 Annual Meeting in Happy Valley-Goose Bay, Newfoundland and Labrador, Canada. The presentation discusses impacts and mitigation techniques for hydropower developments and looks at the issue of barriers in general, including smaller projects such as culvert installations.

Figure 1. *Historical distribution of Atlantic salmon (source: Behnke and Tomelleri, 2002).*

Legislative and Policy Context

The Federal Fisheries Act and the Species at Risk Act are the two key pieces of legislation that dictate how Atlantic salmon are managed in Canada. These Acts are supported by Canada's Policy for the Conservation of Wild Atlantic Salmon. It is important to note that there are a number of other federal, provincial and aboriginal Acts, agreements and policies that contribute to the management of salmon throughout Canada.

Federal Fisheries Act (FA)

Of importance to the management of Atlantic salmon and barrier mitigation, the FA manages threats to the sustainability and ongoing productivity of Canada's commercial, recreational and Aboriginal fisheries. The FA provides Canada's Minister of Fisheries and Oceans with the ability to develop regulations in order to enter into agreements with other federal departments, provinces and others for the effective management of fisheries resources, including wild Atlantic salmon habitat.

The two key sections of the FA relevant to this topic are:

Section 20.(2): *If the Minister considers that doing so is necessary to insure the free passage of fish, the owner or person who has the charge, management or control of an obstruction shall*

- *(a) remove the obstruction*
- *(b) construct a fishway*

(c) *implement a system of catching fish before the obstruction, transporting them beyond it and releasing them back into the water;* and,

Section 35.(1): *No person shall carry on any work, undertaking or activity that results in serious harm to fish that are part of a commercial, recreational or Aboriginal fisheries, or to fish that support such a fishery.*

Federal Species at Risk Act (SARA)

In Canada, species at risk are identified through processes put in place under the federal SARA and similar provincial laws. COSEWIC, which operates at arm's-length from government, assesses candidate species using established criteria to assign a designation. COSEWIC assessed that there were 16 Designatable Units (DUs) of Atlantic salmon in eastern Canada. Of these, one was assessed extirpated (Lake Ontario DU), five were assessed as endangered, one was assessed as threatened, with the remainder either as special concern or not at risk. For the most northern DU, Ungava Bay, there was insufficient information to assess status.

Canada's Policy for the Conservation of Wild Atlantic Salmon

(http://www.dfo-mpo.gc.ca/fm-gp/policies-politiques/wasp-pss/wasp-psas-2009-eng.htm)

The Policy for the Conservation of Wild Atlantic Salmon was developed as part of the response to address the decline in salmon populations. Strategies and action plans are developed under the Policy to address: the need for monitoring and assessment of population status; the conservation and protection of Atlantic salmon habitat; the integrated fisheries management planning process; a collaborative approach to conservation; and, a post-season review process.

The Policy is intended to transform the approach to conserving Atlantic salmon, their habitat, and dependent ecosystems. Key elements of the policy recognize that: protection of the genetic and geographic diversity of salmon is essential; shared stewardship and partnerships will help to achieve conservation objectives; success in salmon conservation relies on addressing factors in their freshwater, estuarine and marine habitats; ecosystems must be considered when making management decisions; and importantly management decisions must be based on good scientific information and consider biological, social, and economic consequences.

Federal Programs

Atlantic Salmon Endowment Fund (ASEF)

The ASEF was a one-time $30 million conditional grant to invest in the conservation and enhancement of wild Atlantic salmon and its habitat. The income earned from ASEF is used to fund projects that contribute to salmon restoration and conservation mainly in the freshwater environment, although marine environment projects are also considered for funding in some cases.

The purpose of ASEF is to achieve healthy and sustainable wild Atlantic salmon stocks in Atlantic Canada and Quebec. The types of projects that are eligible for funding through ASEF include those that maintain, protect and enhance Atlantic salmon and their habitat, rebuild stocks and restore salmon populations, and are related to watershed planning.

Habitat Stewardship Program for Species At Risk (HSP)

The overall goal of the HSP is to provide financial support for stewardship activities that contribute to the survival and the recovery of designated flora and fauna and their habitats. Eligible recipients of HSP funding include not-for-profit organizations, Aboriginal organizations, educational institutions, community associations and local groups, private individuals and companies, and provincial, municipal and local governments.

Aboriginal Funds for Species at Risk (AFSAR)

The AFSAR Program helps achieve the goals of the Species at Risk Program in Fisheries and Oceans Canada (DFO), as well as the broader Government of Canada three part strategy for the protection of wildlife species at risk that includes SARA, the Accord for the Protection of Species at Risk and activities under the HSP.

The objectives of the AFSAR Program are to have stable or increasing populations of species at risk. To attain this goal, the AFSAR Program assists Aboriginal communities and organizations to build capacity for their participation in SARA implementation and to undertake activities that protect the habitats of species at risk.

Recreational Fisheries Conservation Partnerships Program (RFCPP)

(http://www.dfo-mpo.gc.ca/pnw-ppe/rfcpp-ppcpr/index-eng.html)

Canada is well known for its recreational fisheries. Over the years, recreational fisheries have consistently faced multiple threats, including pollution, invasive species and habitat loss. Reasons for habitat loss include habitat degradation and erosion, barriers to fish migration and water flow alterations. There is, however, potential to address these historical impacts through restorative action and partnerships. To this end, legislative amendments to the FA were recently put in place to strengthen cooperation with third parties in areas of common interest. These changes now allow the Minister of Fisheries and Oceans to enter into agreements with third parties to undertake activities to restore fisheries habitat.

The program aims to bring like-minded partners and their resources together with the common long-term goal of enhancing the sustainability and ongoing productivity of Canada's recreational fisheries. The RFCPP funds many different types of restoration projects. Examples of commonly-funded projects include stream, lake and floodplain habitat restoration, fish access improvements, stream channel and bank erosion control and stabilization, ocean habitat restoration and enhancement and chemical manipulations to improve water quality (e.g. aeration and liming).

Note: Specifics related to funds administered through these programs can be found in Canada's Annual Progress Reports to NASCO (http://www.nasco.int/implementation_plans.html).

Aboriginal Traditional Knowledge

The southern Inuit of Labrador and other aboriginal groups have a strong spiritual connection to the land and animals, including Atlantic salmon, found in the region. The land and ocean is a resource from which Inuit, First Nations and Metis draw the necessities of life. Aboriginal groups in Labrador harvest Atlantic salmon for cultural and ceremonial purposes, as a healthy food source and to maintain strong links to the land and ocean. They have traditional knowledge and understanding of the resources and land around them which has been gained through years of living from the land. It is for this reason that land use planning and projects can benefit from early input from these groups as development occurs. Aboriginal traditional knowledge is a means to protect, preserve and sustain future development of the land's vast natural resources for generations to come.

New economic ventures such as mining and forestry operations, highways and hydroelectric plants all bring certain challenges that can negatively impact land, water and animals including the migratory Atlantic salmon. Inuit, First Nations and Metis have extensive knowledge regarding Atlantic salmon and river systems and the gathering and documentation of traditional knowledge will assist governments in better land use planning and project development, specifically as it relates to Atlantic salmon.

All levels of government, federal, provincial and aboriginal need to work together to ensure projects and land use plans are in the best interest of the people and the resources on which they depend. Consultation and involvement by aboriginal groups in all stages of a development are key to the successful and sustainable approaches we will need into the future.

Approaches to Improve River Connectivity

The impacts of barriers to migratory species are well known and include the blocking of migratory routes both upstream and downstream, alteration of bed loads and spawning substrates, water temperature changes and alteration of flows at significant periods in fish development. Barriers can take many different forms such as hydro developments, mill ponds, stream alterations such as straightening of river channels and poor bridge or culvert installations. While the cumulative impacts from these projects have been great and continue to impact fish recruitment, there is a strong history of trying to address these issues and in particular, recent efforts to mitigate and implement corrective measures are gaining momentum.

The following case studies are used to illustrate the issues, mitigation techniques and challenges associated with barrier remediation in eastern Canada.

Case Studies

Case Study #1 - Moisie River

Location: Located on the Moisie River (tributary to the Gulf of St. Lawrence) in Quebec.

Figure 2. *Improving the Katchapahun fishway on the Moisie River. Source: Daniel Girard, Project Coordinator.*

Partnerships: Protection Association of the River Moisie Inc. (APRM), Quebec Ministry of Forests, Wildlife and Parks, DFO

Project Description and Mitigation Efforts: The fishway was commissioned in the 1970s and is an essential component of salmon management, allowing salmon access to spawning grounds that are upstream of a natural barrier. Since 2000, APRM has been responsible for the operation and maintenance of this fishway. In 2014, the APRM obtained financial support from various partners for the project to improve the fishway. Recently works were undertaken on the fishway to lower the intake threshold by 45cm in order to allow it to operate under flow conditions ranging from 210m^3/s to 350m^3/s.

Case Study # 2 - Mactaquac Dam

Location: Located on the Saint John River (tributary to the Bay of Fundy) in New Brunswick.

Partnerships: NB Power, DFO

Project Description and Mitigation Efforts: The dam was commissioned in 1968 and provides 20% of New Brunswick's power demand. A small fishway leads fish to a collection gallery where they are captured, sorted by species, measured, counted, and sometimes tagged for various studies. Subsequently, fish are trucked and released at various locations upstream of the dam. Some salmon from the Tobique River (a tributary to the Saint John River) are brought to the hatchery for broodstock. During subsequent years, hatchery returns captured at Mactaquac are sorted and trucked to the Tobique River.

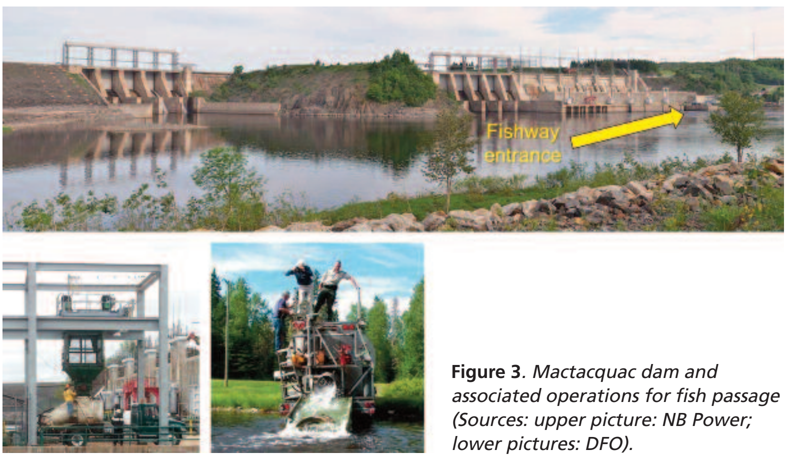

Figure 3. *Mactacquac dam and associated operations for fish passage (Sources: upper picture: NB Power; lower pictures: DFO).*

Although the structures are owned by NB Power, DFO manages fish passage activities. Also, co-operation with NB Power is required to operate generation unit #1 at certain levels (40-60MW) to maximize the attraction flow and reduce turbulences at the entrance of the fishway. In addition to Atlantic salmon, more than 300 tons of alewives and blue back herring are transported above the dam each year.

At this time, there is no protocol for downstream migration. However, the facility is under review for a partial removal, a full removal, or a major refurbishment. All three options include consideration for both upstream and downstream migration. A decision on the dam will be taken by 2016. As a conservation measure, all salmon fisheries on the Saint John River system have been closed.

Case Study #3 - Tobique Narrows Dam

Location: Located on the Tobique River (tributary to the Saint John River) in New Brunswick.

Partnerships: NB Power, DFO

Project Description and Mitigation Efforts: The dam was commissioned in 1953. The power house has a capacity of 20 MW. The upstream fish passage is provided through a 350 meter long pool and weir fishway. NB Power is responsible for the maintenance of the fishway and performs annual inspections to ensure the fishway is in good working condition. During migration periods, the structure is operated by DFO. Attraction pumps were added in 1999 to increase the attraction flows from $0.6m^3/s$ to $1.8m^3/s$.

For the downstream migration, a controlled spilling procedure is implemented in an effort to reduce pre-smolt passage through the turbines. The theoretical turbine mortality estimate is 6% (Lindroth,

Figure 4. *Controlled spilling at Tobique Narrows dam (left) and smolt wheels installed in the Tobique River (right) (Source: DFO)*

1967) but a radio tagging study in 2006 determined turbine mortality to be between 10-30% (Jones et al, 2007). NB Power was spilling water from the small regulation gate during the peak migration period, however a study evaluating the effectiveness of the control spill indicated that there was no difference between spill and turbine mortality. As a result, the spilling program was stopped in 2012. A new structure to insure a safe downstream migration is under review and should be constructed shortly.

A second initiative is to capture young salmon with smolt wheels installed in the Tobique River upstream of the dam. These smolts are raised to the adult stage at hatchery managed by DFO. Once ready for reproduction, they are released in the river upstream of the dam. Later, when returning adults are captured at other facilities they are trucked upstream of all obstructions and released in the upper Tobique River watershed. In addition, as a conservation measure, all salmon fisheries on the Tobique River watershed have been closed.

Conclusions

Significant challenges remain to remediate the numerous barriers existing in eastern Canada that present a problem to the natural migration of Atlantic salmon. Efforts have been made in recent years to address these challenges through partnerships, research and funding efforts. The work of governments, aboriginal organizations, non-governmental organizations/recreational fishing groups and the public in general, are slowly improving the ability of fish to migrate and access habitat. Despite this, new challenges present themselves in the form of changing climate and additional land-use pressures that will need to be addressed through a combination of integrated planning, research, Aboriginal Traditional Knowledge and furthering partnerships with concerned groups and individuals.

Partnerships will be key to addressing barriers to migration going forward. One example of this collaboration occurs between DFO and Provincial departments to improve fish passage at existing structures. As old structures are being replaced, as in the case of culverts, they are being upgraded to the most recent specifications for fish passage. Additionally, agreements with partners for construction of fishways through and around existing dams and for dam removal are being developed and/or considered. Continuous efforts are undertaken through those partnerships to address fish passage issues. Where mandatory offsetting plans are deemed necessary to compensate for habitat loss, proponents are strongly encouraged to reopen watershed by removing old structures (e.g. abandoned dams) or improving obstruction to fish passage (e.g. hung culverts). Even though an exact number is hard to define, many thousands of square kilometers have been reopened to fish migration in eastern Canada over the last few years.

Notwithstanding the fact that fish passage is a legal requirement under the FA, impediments to fish passage dealt with through partnerships and agreements raise a greater level of awareness and open the doors to voluntary compliance for a brighter future for Atlantic salmon.

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Annex 2

CNL(15)45

The Penobscot River Restoration Project - A multi-stakeholder effort to significantly improve access to historic habitat for Atlantic salmon and other sea-run fish

Overview

The Penobscot River Restoration Project (Penobscot Project) is an unprecedented, innovative and collaborative effort to help restore severely depleted native sea-run fish populations while also maintaining hydropower production in the largest watershed within Maine. Major partners in the project include hydropower companies; federal, state, and tribal governments; and seven conservation groups.

In the 1980s and 1990s, a series of contentious dam relicensing proceedings on the lower Penobscot River failed to result in significant progress for energy interests or fisheries restoration. In 1999, a new owner of the lower Penobscot dams created the opportunity for a new discussion about the future of hydropower development and fisheries management. The company (Pennsylvania Power and Light, later PPL Corporation) along with the US Department of Interior, the Penobscot Indian Nation, the State of Maine, and several conservation groups, decided to explore the development of a comprehensive solution to a large number of issues involving hydropower relicensing, migratory fish passage and ecological restoration on the Penobscot River. This discussion led to the Penobscot River Restoration Project.

The Challenge

The Penobscot River and its tributaries flow from near Mount Katahdin in the North Woods through the heart of Maine to Penobscot Bay. It is the largest river system within the State of Maine, draining 8,570 square miles or over one quarter of the State, and is the second largest in New England. Maine is home to the last remaining wild Atlantic salmon in the United States; the Penobscot's returning run of approximately 1,000 fish (ten year average) is by far the largest remaining run.

For two centuries, the cumulative impacts of dams have caused widespread harm to people and wildlife. Native populations of Atlantic and shortnose sturgeon, American shad, alewives, blueback herring and sea lamprey have also been nearly or completely extirpated from the Penobscot. Populations of other native sea-run species, such as American eel, rainbow smelt, striped bass, and tomcod, are remnants of their historical abundance. Researchers have linked the decline of inshore cod and groundfish populations to the damming of large rivers, such as the Penobscot, in the 1800s and the subsequent loss of the once prolific river herring runs.

Wildlife along the river corridor has been impacted by the dams. Fish eating birds, such as bald eagles and ospreys, need open-river stretches in winter. Songbirds suffer from decreased abundance of macroinvertebrates. Fish trapped in impounded waters above dams accumulate toxins which pass up the food chain. People have lost recreation and traditions (paddling, salmon angling), business, and culture. The Penobscot Indian Nation, whose reservation includes river waters and islands, are unable to fully exercise sustenance treaty fishing rights and cultural and ceremonial practices.

A 2004 National Academy of Sciences (NAS) report on Atlantic salmon in Maine affirmed that there are simply too many dams on the Penobscot River for successful salmon restoration, and that many other species would also benefit from dam removals. The NAS recommended a ‘primary focus’ on the Penobscot. The NAS's list of ‘Urgently Needed Actions’ is ‘a program of dam removal, with priority on those dams whose removal would make the greatest amount of spawning and rearing habitat available.’ The objective of opening access to historic habitat has since been echoed in numerous state, federal and tribal fisheries management plans. The Penobscot Project squarely addresses these recommendations.

The Plan

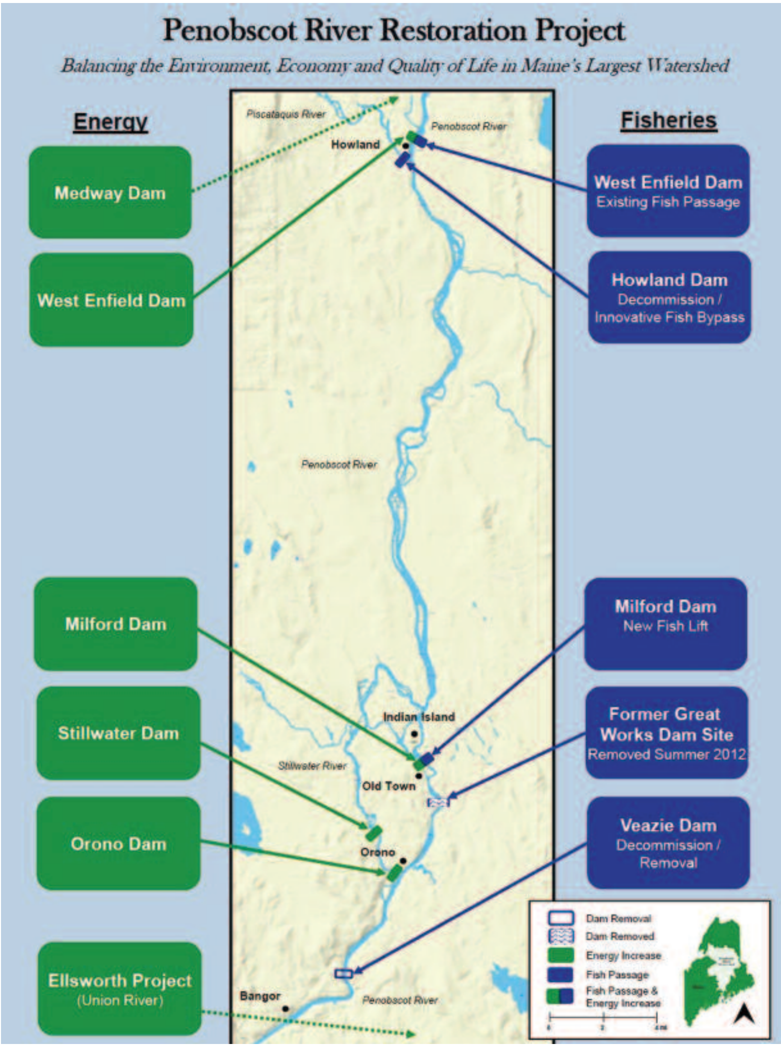
In June 2004, the Penobscot River Restoration Trust signed the Lower Penobscot River Multi-Party Settlement Agreement (‘the Agreement’), a collaborative, far-reaching blueprint for a win-win, public-private effort to rebalance hydropower and sea-run fisheries on the Penobscot River. Since that time, pursuant to the agreement, the Penobscot Trust has exercised an option and has: purchased and decommissioned three Penobscot River dams; removed the two most seaward dams (Veazie and Great Works); and is currently building a fish bypass around the third, Howland. Under the plan, the power company would have the opportunity to apply for permits, with support from the other parties, for incremental energy increases at six existing dams. These increases would maintain or potentially exceed pre-project energy generation.

Projected benefits of the Penobscot Project are expected to include:

- providing unobstructed access to 100% of historic habitat for 'lower river' species such as Atlantic and shortnose sturgeon and striped bass;
- significantly improved access to nearly 1,000 miles of historic river habitat for endangered Atlantic salmon and other 'upper river' species of native sea-run fish;
- maintenance of hydropower generation;
- restoration of critical ecological functions that will benefit native plant and animal communities in the river, estuary, and Gulf of Maine;
- a cleaner, healthier, and more resilient river;
- revitalisation of the Penobscot Indian Nation's culture and traditions;
- new opportunities for economic and community development in riverside communities;
- enhancement of outdoor recreation such as fishing, paddling, and wildlife watching; and
- resolution of a number of longstanding issues and avoidance of future uncertainties.

The river has been the ancestral home to the Penobscot Indians for more than 10,000 years. Members of the Penobscot Indian Nation will benefit from a free-flowing river that will re-connect their homeland to the Atlantic Ocean, an important migration and trade route. Renewed connectivity will also bring sea-run fish to the nation, and revitalize opportunities for historic traditions. A restored river will help to strengthen and reinforce the Tribe's cultural heritage and identity.

Benefits of the Penobscot Project extend to the whole ecosystem and the Gulf of Maine. Endangered Atlantic salmon, American shad, alewives, blueback herring, and seven other species of migratory fish are expected to rebound, fueling large-scale restoration of the Penobscot ecosystem and benefiting its diverse wildlife. Sizeable populations of native fish will provide dependable feeding opportunities for fish-eating birds and mammals such as kingfishers, river otters, osprey, and bald eagles. Waterfowl, such as the Barrows goldeneye, will find winter food in newly open waters; birds of prey



stand to benefit from increases in uncontaminated nutrients from the ocean. Over time, the increase in historic herring biomass (alewife, blueback and shad) could help to restore commercial ground fisheries and other vital ecological links between the Gulf of Maine and the Penobscot River, one of the largest inputs of fresh water to the Gulf.

Some types of recreational fishing opportunities will return and others will expand. The removing of the dams will convert impoundments to free-flowing river, improving water quality and increasing the diversity and abundance of aquatic insects, which are ecologically important to fish and migratory songbirds. New whitewater rapids in the project area will create new canoeing and kayaking opportunities. A downriver trip from Old Town all the way to Penobscot Bay is again possible without portages around dams. Wildlife viewing should improve due to increased species diversity associated with free-flowing river segments, and angling opportunities will diversify over time.

Project status

The Penobscot Trust, working with its many public and private partners, has removed the two lowermost dams. The Great Works Dam was decommissioned and removed in 2012; the Veazie Dam was decommissioned and removed in 2013. A recently constructed fish lift at the Milford Dam, above the reconnected lower river, now allows fish to pass another 40 open miles to Howland. However, the Howland Dam still blocks vast, high quality spawning, nursery and

Before (left) and after (right) the removal of Great Works Dam in 2012. Courtesy of Penobscot River Restoration Trust.

Before (left) and after (right) the removal of Veazie Dam in 2013. Courtesy of Penobscot River Restoration Trust.

rearing headwater habitat. This dam has been particularly harmful to young salmon, typically killing 23% of the salmon smolts migrating to sea each spring. The project is now focused on the construction of a natural fish bypass around the decommissioned Howland Dam. Construction is currently underway with completion anticipated in the early fall of 2015.

In addition, with major support from NOAA, monitoring of the Penobscot Project was initiated in 2009 using a multidisciplinary, before-after approach. This baseline monitoring has provided a snapshot of pre-dam removal conditions and thus an objective basis for evaluating restoration outcomes post Project implementation. Collaboration with research scientists from the Penobscot Nation, University of Maine, US Geological Survey and others provides information on the ecological response to the project under the following priority parameters: (1) physical and geomorphic; (2) water quality (chemical and benthic invertebrates); (3) wetland and riparian community (including invasive species monitoring); (4) fish passage (up and downstream via tagging and hydro-acoustic methods); (5) fish community (presence and abundance); (6) ecosystem function (marine derived nutrients); and (7) Atlantic and shortnose sturgeon reproduction and habitat use (including habitat suitability modeling and active tagging). Monitoring of the Project is ongoing and is integral to evaluation of success.

Annex 3

CNL(15)42

Restoration of upstream and downstream connectivity on the River Rhine

This paper provides a short outline of current developments regarding the restoration of upstream and downstream connectivity on the River Rhine with particular focus on the reintroduction programme for Atlantic salmon. In this context, the paper deals with information about the 'Master Plan Migratory Fish Rhine' and facts concerning bottlenecks in up- and downstream connectivity and the planned measures for the coming years to improve fish migration in the River Rhine and its tributaries.

Background

By the end of the nineteenth century there were still hundreds of thousands of Atlantic salmon migrating upstream in the river Rhine to their spawning grounds. Historical data indicates a catch of almost 250,000 salmon in 1885. After that peak, the catches declined, until the complete extinction of the Rhine salmon. The last salmon was caught in the Rhine in 1958. The extinction of Rhine salmon is closely correlated with the construction of obstacles to migration; other contributory factors were deterioration of water quality and overexploitation of the remaining salmon stocks.

In 1986, a Swiss warehouse storing chemical pesticides burned down. The so-called 'Sandoz disaster' practically wiped out the life in the main stem of the Rhine. Just one year later, Ministers from countries bordering the Rhine agreed the Rhine Action Plan. The Ministers adopted the salmon as a symbol of a healthy Rhine.

When starting the ambitious programme for the ecological rehabilitation of the Rhine, the Member States of the International Commission for the Protection of the River Rhine (ICPR) agreed that migratory fish species, such as the Atlantic salmon, should again colonize the river and its tributaries (Ingendahl et al., 2007). To achieve that goal a restocking programme was started in several areas of the Rhine basin, especially in Germany, France and Switzerland. Since 1990, adult salmon have been regularly recorded in an increasing number of tributaries of the River Rhine and at fish counting stations in the Upper Rhine.

ICPR programmes for salmon and migratory fish

For the benefit of the Rhine and of all waters flowing into the Rhine, the members of the ICPR (Switzerland, France, Germany, Luxemburg, the Netherlands and the European Union) successfully co-operate with Austria, Liechtenstein and the Belgian region of Wallonia as well as Italy. Nine states and regions in the Rhine watershed closely cooperate in order to harmonise the many user interests and protection in the Rhine area.

One of the issues in the ICPR is ecological river restoration, for which the Atlantic salmon has become a key species. In this context the 'Master Plan Migratory Fish Rhine' (ICPR, 2009a) indicates how self-sustaining, stable populations of migratory fish can be reintroduced to the Rhine catchment within a reasonable period of time and at reasonable cost. The salmon serves as a symbol representing many other migratory fish species (such as sea trout, sea lamprey, allis shad and eel). Furthermore, measures aimed at reintroducing migratory fish have positive effects on the incidence of many more species of fauna and flora and are appropriate for improving the entire ecology of the Rhine. This considerably supports the main objective of the European Water Framework Directive (WFD) to achieve a 'good status' or a 'good potential' of water bodies.

An important step in improving river continuity was the Fifteenth Conference of Rhine Ministers held in 2013 (ICPR, 2013). This Conference adopted a precise schedule for restoring the continuity of the Rhine for fish migration.

In order to achieve the objectives of the programme 'Rhine 2020' and of the 'Master Plan Migratory Fish Rhine' in the main stem of the Rhine, Ministers acknowledged *inter alia* that:

- salmon stocking can be reduced step by step in parts of the River Sieg system, a tributary in the lower reaches of the Rhine, even though such stocking measures remain absolutely essential in the long term in the upper reaches of the Rhine, in order to increase the number of returnees and to enhance the slowly recovering natural reproduction;
- the restoration of migration routes represents an important management aspect for the implementation of the WFD and Swiss law on water protection;
- migratory fish also play a role in the implementation of the European Marine Strategy Directive;

- for juvenile salmon, downstream migration in the turbine areas is critical because of the great danger of injuries, particularly where there are successive hydropower plants. For 2014-2016, the ICPR has the mission to work intensively on the joint determination of innovative techniques of downstream migration at transverse structures; and
- due to ongoing measures, river continuity upstream as far as Basel is becoming more and more realistic and plannable. This will open the access to the existing spawning grounds of migratory fish in the rivers Birs, Wiese, Ergolz and Aare (Switzerland) by 2020.

In order to achieve the objectives of the programme ‘Rhine 2020’ and of the ‘Master Plan Migratory Fish Rhine’ in the main stem of the Rhine, Ministers acknowledged that:

- the Haringvliet sluices on the North Sea coast will be partly opened in 2018;
- the fish pass at the Strasbourg impoundment will be operational in 2015;
- construction work on the fish pass at the Gerstheim impoundment will start in 2015 in order to reconnect the Elz-Dreisam area with the Rhine;
- the experience and assessment of the effectiveness of the existing fish passes built in the river system, to date, will contribute to improving the technical solutions still to be constructed;
- the transfer of fish into the old bed of the Rhine in the region around the Vogelgrün/Breisach impoundment is a technical challenge. With respect to the upstream migration through the Upper Rhine as far as Basel, the ICPR facilitated an exchange of experts in 2014, taking into account the results of studies to date, in order to contribute to finding the optimal technical solution; and
- an efficient fish pass system must be planned and implemented at the Rhinau, Marckolsheim and Vogelgrün impoundments on the Upper Rhine, so that by 2020 fish may reach the old bed of the Rhine and Basel.

Concerning the Rhine tributaries, the Ministers agreed on the following:

- by constructing fish passes at the impoundments, the continuity of the River Moselle as far as Schengen (tri-border region France-Luxembourg-Germany) must be successively restored;
- fish passability must be restored at all existing transverse structures in all programme waters of the 'Master Plan Migratory Fish Rhine';
- as a matter of principle, no new migration obstacles may be constructed in the programme waters and, as far as possible, no obstacles to migration may be constructed in the remaining free-flowing stretches in order to conserve these stretches as spawning grounds and juvenile habitats; and
- the measures in the 'Master Plan Migratory Fish Rhine' should be extended to several tributaries of the High Rhine and the Aare (Switzerland) which, according to an inventory established in 2012, present more than 200 hectares of additional habitat for juvenile salmon.

Upstream connectivity in the River Rhine

In total, more than 1,200 hectares of spawning and juvenile salmon habitats are available in the Rhine catchment area. By 2012, about 256 hectares had been made accessible. That means that for the entire catchment area, more than one fifth of the potential productive habitat is accessible.

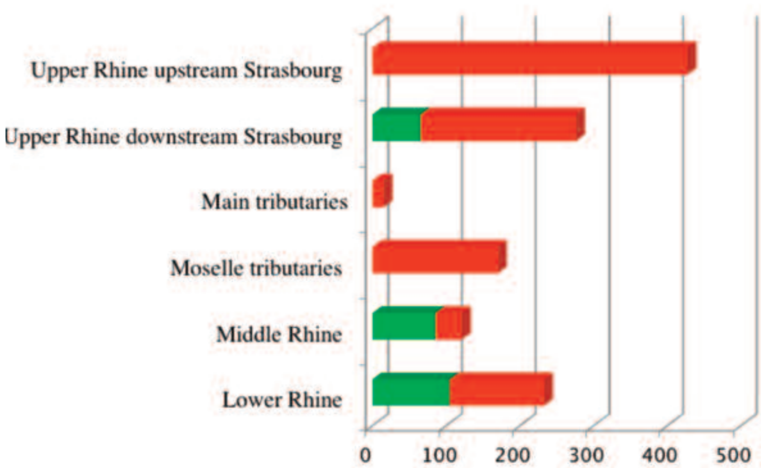
The current habitat availability and accessibility to upstream migrating fish is shown in Figure 1 for individual sections of the River Rhine. In the Lower Rhine, Middle Rhine and Upper Rhine (downstream of Strasbourg) 45%, 69% and 25% of the spawning habitat, respectively, is accessible to salmon. The important salmon habitat in the Upper Rhine (upstream of Strasbourg) and in the River Moselle, the second largest tributary of the Rhine, are still not accessible to salmon. It is a big challenge for the coming years to open these areas to migratory fish.

Up to 2013, almost 500 barrage weirs were made passable for fish by building fish ladders or by removing the barriers. The most commonly used facilities are different types of pool passes.

Special action needs to be taken at the main 'front door' of the Rhine and Meuse rivers, the Haringvliet, which is currently closed from the sea by a dam that only allows downstream migration of fish. In 2018, the dam will be partially opened, in order to facilitate upstream migration of fish.

In the Upper Rhine, five barrages still have to be provided with fish passes in order to meet the Rhine objective of 'passability' to Basel by 2020. In 2015, the fish pass at the Strasbourg impoundment will be operational and construction work on the fish pass at the Gerstheim impoundment will commence. With the help of these two new fish passes, the Elz-Dreisam area will be reconnected to the Rhine. The experience and assessment of the effectiveness of the fish passes constructed in the river system to date will contribute to improving the technical solutions where there are still barriers to fish migration. The transfer of fish into the old bed of the Rhine in the region around the Vogelgrün/Breisach impoundment is a technical challenge. An efficient fish pass system at the Rhinau, Marckolsheim and Vogelgrün impoundments on the Upper Rhine is still to be planned and implemented.

Figure 1. *Accessible (green) and non-accessible (red) spawning and juvenile habitat surfaces (ha) for Atlantic Salmon in the Rhine system divided into different river sections in 2012*



Downstream connectivity in the River Rhine

Passage of fish migrating downstream through turbines at hydropower plants causes damage, the extent of which depends on the fish species concerned, the size of the fish and the technical specification of the plant (ICPR, 2009b). In the Rhine and those tributaries with numerous hydropower plants, damage to fish is cumulative during their downstream migration. For salmon, in particular, this mortality poses a threat to the survival of the population, as this species returns to its natal stream and losses of the partial population must almost exclusively be balanced by the reproducing population upstream of the hydropower plant. In order to be able to build a self-sustaining population, at least 1% of the downstream migrating smolts are required to return as adults to the spawning grounds. A higher return rate is possible and is the goal.

In order to comply with the objectives established by the Rhine Ministers, the ICPR started with an overview of the bottlenecks for downstream migrating fish, and all Rhine countries collected data. Within the River Rhine catchment, 552 bottlenecks were identified. Only a few obstacles have special facilities installed to protect downstream migrating fish against passage through the turbines. When passing the hydropower installation, fish can be damaged by turbine blades or guiding vanes, by the differences in pressure, and by high flow rates and turbulence. Apart from this ‘direct’ damage, ‘indirect’ effects can also occur, e.g. a higher predation rate after passing a hydropower installation.

The Kaplan turbine is the dominant type in use in the Rhine system, particularly in the main stem of the river. Other types in use are Francis turbines and Banki-Mitchell turbines. In the smaller, recently constructed hydropower stations, the Archimedes screw is sometimes used. The mortality rate of fish varies from under 5% to over 90% for Francis turbines. On average, fish mortality is lower in Kaplan turbines, ranging from under 5% to approximately 20%. A study conducted on the Archimedes screw in the Netherlands showed no fish mortality at all, while another study found a mortality of 5%.

The most important protective measure is to prevent fish from passing through the turbines by using screens. Recently, studies aimed at determining best practice solutions for downstream migrating salmon at hydropower plants have been conducted in the Rhine catchment with the first results expected in 2016.

Conclusions

As a consequence of the improvements in water quality and river continuity in the River Rhine, the Atlantic salmon could be reintroduced. With the growing numbers of fish migrating up the river, it became clear that both upstream and downstream migration of fish had to be facilitated. Hydropower installations represent a serious threat, not only for migrating salmon smolts, but also for eels.

Recently, several developments have focused on smaller hydropower installations (≤ 50m^3/s). The effectiveness of measures implemented must be confirmed on site. For larger installations, new developments are urgently needed.

In addition to the importance of up- and downstream river connectivity, many other issues need to be addressed such as water quality, genetics, stocking and habitat restoration as well as illegal catches of salmon. Much has been achieved to restore the connectivity of the River Rhine, but the issue remains the biggest challenge regarding restoration and protection of migratory fish species.

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Fish pass at Hagestein weir, the Netherlands. Courtesy of Tom Buijse.

Annex 4

CNL(15)43

Maintaining and improving river connectivity: the current position and experience in England

This paper provides an overview of the scale of the historic legacy of obstructions to fish passage and how an innovative approach is being taken to identify priority obstructions and improve river connectivity. It then outlines, how in response to the recent growth in hydropower in England, hydropower guidance has been developed to ensure that migratory fish are protected and that river connectivity is maintained or improved.

Historic legacy of obstructions to fish passage in England and Wales

The Environment Agency has established a geographic database of obstructions across England and Wales. It identified 26,000 obstructions (18,000 of which are man-made) on a river network length of 300,000km, which equates to one obstruction every 11.5km (Figure 1). These range from large dams, which may have been built for navigation and/or milling, to smaller structures, for example, for irrigating water meadows. However, on some rivers the frequency of obstructions can be much greater. For example, on the River Yealm, in south Devon, which is a short moorland spate river, there are over 30 man-made obstructions to migration over a distance of ~18km.

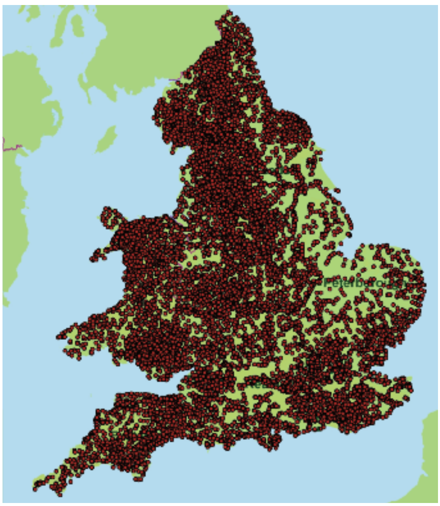


Figure 1. *26,000 obstructions across England & Wales. Courtesy of the Environment Agency.*

The establishment of the geographic database has enabled a much more systematic approach to improving river connectivity and integrating this information into river basin planning including: Water Framework Directive River Basin Plans (and supporting Sea Trout and Salmon Catchment Summaries), Flood Risk Management Plans and Eel Management Plans.

Obstructions have a fundamental impact on both river connectivity and natural river processes. Under the Environment Agency's most recent assessment of reasons for not achieving 'Good Ecological Status' under the Water Framework Directive, physical modifications including obstructions were identified as the most significant factor.

For salmon, these physical modifications can inhibit adults reaching valuable spawning habitat, impact on the survival of smolts migrating to sea, degrade critical salmon habitat and affect water quality and river flows. Obstruction to fish passage is recognised as one of the critical issues affecting England's salmon populations and is a priority for action in England's salmon strategy: *Better sea trout and salmon fisheries 2008 - 2021.*

Padiham Weir on the River Calder, a tributary of the River Ribble in North West England.

Improving river connectivity

Through the first cycle of the River Basin Management Planning (2009 - 2015) under the EU Water Framework Directive[1] , improving river connectivity and addressing obstructions to fish passage was highlighted as a priority to prevent deterioration and improve ecological status. Through considerable effort by the Environment Agency, Natural England, the Department for Environment, Food and Rural Affairs (Defra), Rivers and Wildlife Trust, fisheries interests, landowners and community groups working together, between 2009 -

[1] *http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm*

2014, more than £22million was invested in addressing 229 obstructions across England and Wales (Figure 2). This was, in many ways, made possible through Defra's River Improvement and Catchment Restoration Funding programmes.

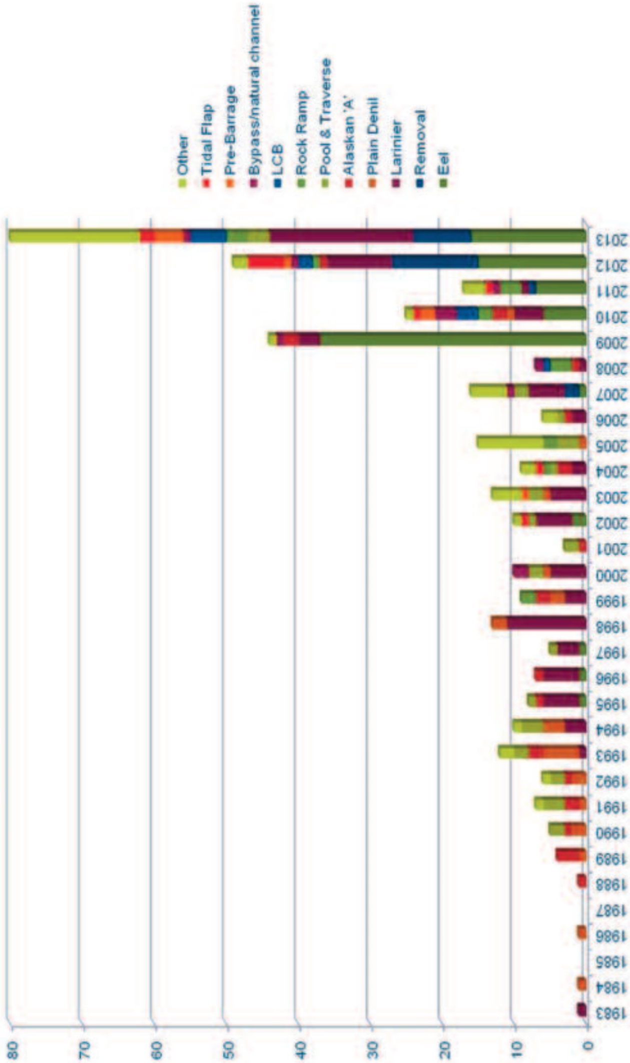


Figure 2. *Fish passage improvement schemes across England and Wales 1983 - 2013. Courtesy of the Environment Agency.*

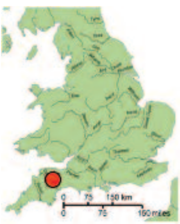
The improvements that have been made to river connectivity have included schemes from sea to source, ranging from installing tidal flaps and fish friendly side-hung gates at the tidal limit to removing obstructions completely or installing a wide range of fish passage easements and passes to the benefit of multiple species (Figure 2).

In improving river connectivity, the hierarchy in decision making that the Environment Agency follows is: remove the obstruction> construct a natural bypass> modify the obstruction to make it passable> install a fish pass. Wherever possible the emphasis is on working with natural processes and maximizing benefits for multiple species and habitats, whilst not compromising flood risk management requirements.

Figure 3. *Location of 63 fish passes and easements on England's 42 principal salmon rivers constructed between 2009 and 2014. (Includes River Severn catchment which extends into Wales). Courtesy of the Environment Agency.*

For England's 42 principal salmon rivers, 63 fish passes and easements were built between 2009 and 2014, which has improved access to 3,700km of river (Figure 3). This is the equivalent of the distance from London to the west coast of Greenland. Eight of these 63 fish passes and easements were linked to hydropower schemes.[2]

Case study (a): River Mole Head Weir Natural Fish Pass[3]



The River Mole is an important sub-catchment of the River Taw in North Devon and provides the primary spawning and nursery area for Atlantic salmon and sea trout in the Taw catchment. The River Taw is one of England's 42 principal salmon rivers and is currently assessed as being 'probably at risk' (failing to meet or exceed its salmon conservation limit in 4 years out of 5)[4].

Head Weir was constructed in c.1840 to feed an abstraction to Head Mill and was the most downstream obstruction on a tributary of the River Taw, the River Mole. Though a Denil fish pass had been constructed in 1991/92, when the weir crest was raised by the then owners, there were a number of factors that made it ineffective. Head Weir was identified as an issue in the River Taw Salmon Action Plan (2003) and was seen as contributing towards the water body failing to reach Good Ecological Status under the Water Framework Directive.

In 2007, the Environment Agency surveyed seven weirs on the Taw system and all were judged to impede fish access upstream. Head Weir was amongst the worst. This led to the concept of the Westcountry River Trust's Taw Access over Weirs (TAW) Project, which

Head Weir before and after construction of a natrural fish pass. Courtesy of the Environment Agency.

[2] *These have all been built since 2012. This information may not have been recorded for earlier sites. Environment Agency National Fish Pass Database.*

[3] *European Centre for River Restoration – Case Study: River Mole Head Weir Replacement (pdf).*

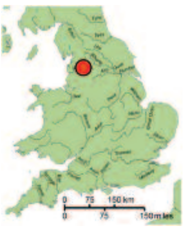
[4] *ICES Annual Assessment of Salmon Stocks and Fisheries in England and Wales, 2014.*

was supported by the River Taw Fisheries Association, Defra, the Environment Agency, the Association of Rivers Trusts and the Interreg Atlantic Area AARC Project.

In 2009, the Environment Agency funded the design and in 2010 Westcountry Rivers Trust secured funding from Defra's River Improvement Fund. A natural fish pass was chosen as it would provide fish passage for a variety of fish species, operate over a wide range of flows, require minimal maintenance and was aesthetically in keeping with the location.

The work was undertaken by the Environment Agency and completed at the end of 2010, at a cost of £325,000. As a consequence of the project, over 40km of spawning habitat has been made accessible, which is estimated to have the potential of producing up to 2,000 additional salmon smolts each year. An immediate benefit was seen with many salmon being observed upstream of the fish pass the following year.

Case study (b): River Calder Padiham Weir removal [5]



The River Calder is a tributary of the River Ribble in North West England and has numerous weirs and dams associated with its industrial past. The River Ribble is one of England's 42 principal salmon rivers and is currently assessed as being 'at risk' (failing to meet or exceed its salmon conservation limit in 4 years out of 5).

Padiham Weir was built in the 1950s to provide water to a now demolished power station. At 1.85m it was the largest weir on the River Calder and created a total barrier to all fish migration.

Padiham Weir before and during construction of the rock ramp.

[5] *UK River Restoration Centre, Manual of River Restoration Techniques 12.4 Weir lower and rock ramp construction Padiham Weir River Calder (pdf).*

In 2010, the Environment Agency and Ribble Rivers Trust led a £400,000 project to lower the weir and build a rock ramp in partnership with local fishing clubs to improve river connectivity for multiple fish species. Since this project was completed, further measures have been taken by the Environment Agency and Ribble Rivers Trust to address more obstructions upstream which have included full weir removal, rock ramps, Alaskan A fish passes, Larinier fish passes and pre-barrages. Salmon and sea trout are now able to migrate from the sea to very near to the source of the formative tributaries of the River Calder for the first time in 150 years thanks to a lot of hard work and partnership working. In 2012 and 2013, salmon kelts and carcasses were observed above Padiham and in 2014, for the first time, salmon fry were found on the River Calder by the Environment Agency during its electric fishing surveys.

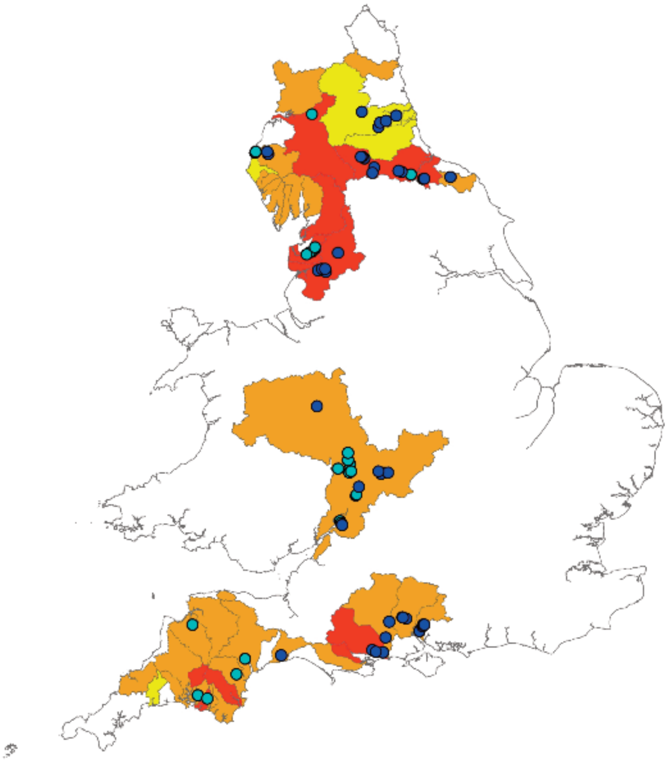


Figure 4. *72 super critical (dark blue) and high priority (light blue) obstructions on England's 42 principal salmon catchments. (Includes River Severn catchment which extends into Wales). The colours indicate the present state of salmon stocks (2014)[4]: red = 'at risk'; orange = 'probably at risk'; yellow = 'probably not at risk'; green = 'not at risk'. Courtesy of the Environment Agency.*

Identifying priority obstructions

To help optimise the environmental outcomes from improving river connectivity, a matrix has been established to identify super-critical and high priority obstructions where improved passage is most likely to deliver for multiple species (salmonids, coarse fish and eels) and multiple legislative drivers (Habitats Directive, Water Framework Directive and the Salmon and Freshwater Fisheries Act 1975). For England's salmon rivers, 72 obstructions have been identified through this process (Figure 4). Complementing this, catchment-based priority obstructions will be identified for England's principal salmon rivers in partnership with local stakeholders as part of a process of updating Sea Trout and Salmon Catchment Summaries. To help with this, the Environment Agency is developing a phone-based app that will enable people to provide information on obstructions in a way that links to the geographic database, through the process known as 'crowd sourcing' data.

Hydropower development in England

In 2009, the UK signed up to a legal obligation to meet 15% of its energy demand from renewable sources by 2020[6] and hydropower is seen as having the potential to make a small but useful contribution to this target. English hydropower currently generates 0.03% of the electricity consumed in the UK[7]. The majority of hydropower development in England is run-of-river schemes and the average size is less than 100kW.

Figure 5. *Location of permitted hydropower schemes across England and Wales based on Environment Agency data up to December 2013. (Not all schemes may have been or may not still be operational). Courtesy of the Environment Agency.*

To encourage development of renewable energy schemes, such as hydropower, a feed-in tariff scheme was introduced. The prospective expansion of hydropower caused concern, especially amongst fisheries interests, about the

[6] *DECC (2011) National Renewable Energy Action Plan for the UK. Article 4 of the Renewable Energy Directive 2009/28/EC.*

[7] *DECC (2013) Electricity generation and supply figures for Scotland, Wales, Northern Ireland and England, 2004 to 2012 Spreadsheet].*

potential effect of hydropower schemes on fish populations including salmon.

The Environment Agency has permitted around 350 schemes in the last 40 years and 223 since the 2009 introduction of subsidy support through the Government feed-in tariff[8] . However, not all of these have been built. It is currently estimated that about 220 hydropower schemes are operating across England and Wales (Environment Agency, personal communication). The Environment Agency receives about 30 - 40 applications for new developments each year. Figure 5 shows the distribution of hydropower schemes across England and Wales.

Guidance

The Environment Agency is a key regulator for hydropower development in England and is responsible for addressing effects on the aquatic environment and fisheries.

Undertaking works in rivers and impounding and abstracting water are subject to permitting by the Environment Agency. In determining permits, the Environment Agency is required to address impacts on:

Must not prevent the achievement of **Water Framework Directive (WFD) objectives** at water body level

Must maintain or improve **fish passage and fisheries**

Must not have unacceptable impacts on **protected sites or species**

Must not have unacceptable impacts on the **rights of other water users**

Figure 6. *Four tests to ensure that hydropower developments do not have unacceptable impacts on flows. Courtesy of the Environment Agency.*

[8] *Figures up to December 2013.*

water flow and availability and other permitted water users; fish and fisheries; protected wildlife and habitats; and the management of flood risk.

In meeting its duties, the Environment Agency has developed guidance in consultation with the hydropower industry and fisheries interest groups.

Good practice guidance was first issued in 2009. This has subsequently been updated to include high-head schemes and particularly take on board concerns associated with the management of flows. The Environment Agency's 'Guidance for run-of-river hydropower development' was published in January 2014[9].

Environmental protection safeguards

To ensure that the environment is protected, the Environment Agency has issued detailed technical guidance on: flow and abstraction management; geomorphology (including weir pools); fish screening requirements; fish passage; Water Framework Directive, nature conservation and heritage; and flood risk.

Hill Bridge hydropower intake on the River Tavy in South West England - protected river flows, fish screening and improved fish passage saves hundreds of smolts every year.

To protect flows and maintain and improve river connectivity, four tests have been developed to ensure that hydropower developments do not have unacceptable impacts (see Figure 6).

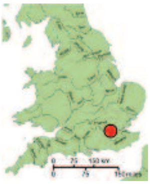
On a number of rivers, hydropower developments have been accompanied by new fish passes that have improved the migration pathways for salmon and other fish. For example, on the River Tavy

[9] *https://www.gov.uk/government/publications/good-practice-guidelines-to-the-environment-agency-hydropower-handbook*

at Abbey Weir and Hill Bridge on the eastern edge of the Dartmoor National Park in South West England, the Environment Agency secured improvements in prescribed flows, fish screening and fish passage at three abstractions used for hydropower schemes operated by South West Water. The total investment was over £1million and it is estimated that the fish screens save hundreds of smolts every year.

Several pieces of targeted research have been commissioned by the Environment Agency examining screening efficiency, weir pools and the potential for cumulative effects[10] and the Environment Agency and Cefas (Centre of Environment, Fisheries and Aquaculture Science) are working with the Game and Wildlife Conservation Trust to investigate possible impacts of Archimedes hydropower schemes on the behaviour of emigrating salmon and sea trout smolts.

Case study (c): Romney Weir hydropower scheme on the River Thames



The Romney Weir hydropower scheme on the River Thames was built on an existing weir, which provides for navigation and flood risk management. Although there was an historic Denil fish pass on the weir it was only suitable for upstream passage of salmon, sea trout and large coarse fish. As part of the hydropower scheme, the developers were required to install a multi-species Larinier fish pass. It was positioned adjacent to the river bank and co-located with the outflow from the turbines to maximize attractant flow and optimise upstream fish migration. To protect the integrity of the ecologically important weir pool, which provides fish spawning and holding

Pre-Hydropower Scheme **Post-Hydropower Scheme**

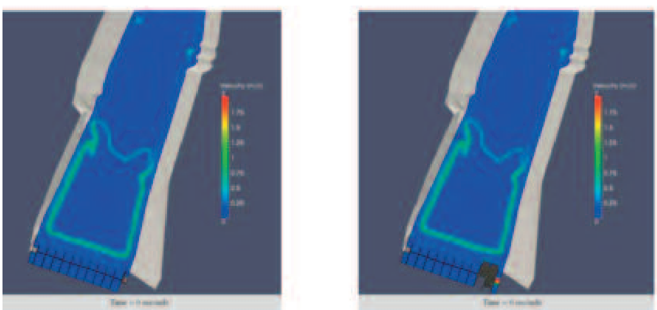
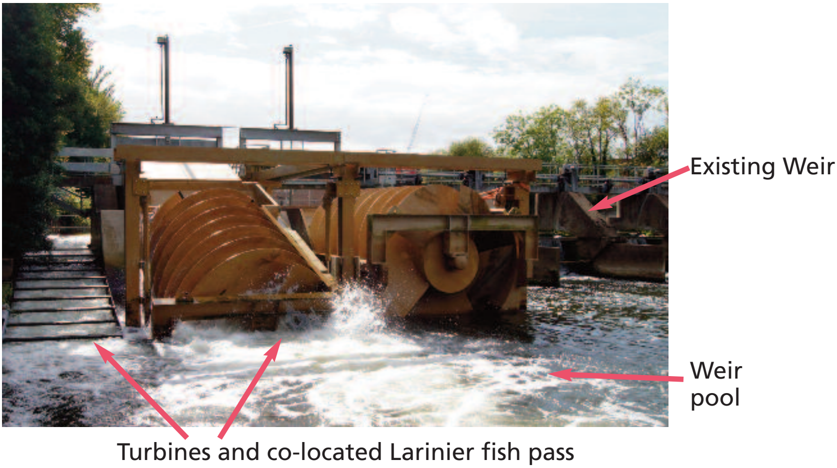


Figure 7. *Romney hydropower scheme - pre and post water velocities in the ecologically important weir pool. Courtesy of the Environment Agency.*

[10] *Environment Agency (January 2015) Cumulative effects of hydropower schemes of fish migration and populations – Report SC10078 [available via www.gov.uk]*

habitat, a flow split was agreed across all of the competing requirements for flow: navigation lock, side channels, ecologically important habitat, fish pass, hydropower turbine etc. to meet the needs of the environment whilst providing for power generation. A Computational Fluid Dynamics investigation into the impact of the hydropower scheme on the weir pool suggested little impact to water velocities and depth, Figure 7[11]*.*



Potential cumulative effects

With an increasing number of hydropower schemes and a concern about whether the effect of individual schemes could be cumulative, the Environment Agency commissioned a literature review and the development of a model to assess the impact of multiple hydropower schemes on salmon. The literature review showed that multiple schemes have the potential to increase effects, but most of the studies were on overseas sites which were much larger than those typical in England.

The model which tested various scenarios of between 1 to 6 hydropower schemes using hypothetical data based on the Northumberland River Coquet, indicated a range of effects from +18% to -12% of the numbers expected of returning adult salmon. The study found that the variation in effect was highly dependent on the assumed passability of existing barriers, the efficiency of any constructed fish pass, and the location of the scheme on the river with downstream-sited schemes having the potential to cause larger

[11] *Environment Agency (2013) Romney Weir Hydropower CFD Modeling – report by Arup*

positive or negative effects. Positive effects were always driven by the inclusion of improved fish passage at individual schemes. The study highlights the importance of careful design of schemes and implementation of mitigating measures at individual sites.

Potential effects of Archimedes screw turbines on salmon smolts

The Environment Agency and Cefas are working with the Game and Wildlife Conservation Trust to investigate the effect of a small low-head hydropower scheme on the behaviour of emigrating wild salmon and sea trout smolts on the River Frome in Dorset. Acoustic transmitters surgically implanted into the peritoneal cavity and submersible acoustic receivers positioned at strategic positions around an Archimedes hydropower scheme and throughout the associated river catchment are being used to monitor the behaviour of emigrating smolts to where the estuary meets the sea. PIT tagged salmon smolts are also being released upstream of the mill to assess impacts. A similar acoustic study is currently being undertaken at a hydropower scheme on the River Ribble. At present the numbers of tracked smolts has been low so the results are inconclusive. The research is ongoing.

Conclusions

Maintaining and improving river connectivity is a critical issue to safeguard England's salmon populations. On England's principal salmon rivers, the Environment Agency has identified 72 super critical and high priority obstructions, which when addressed would open up access to a significant amount of river habitat, providing the potential for a substantial increase in smolt output.

There is continuing interest in hydropower development in English rivers. Through engagement and discussion with hydropower developers along with environmental and fisheries interests, guidance is in place to enable development while addressing environmental and fisheries issues. On a number of rivers, hydropower developments have been accompanied by new fish passes that have improved the migration pathways for salmon and other fish. Targeted research has been commissioned to assess effects and impacts of hydropower developments.

Annex 5

CNL(15)41

Progress in developing best available technology for hydropower generation and other initiatives to improve fish passage in Sweden

Hydropower and environmental legislation

In Sweden, hydropower is an important form of electricity production. About 2,100 hydroelectric power stations produce 40% of the total electricity generated in Sweden. Nuclear power accounts for 40% of electricity production and other sources, mainly wind turbines, the remaining 20%. The largest 206 hydropower stations account for 93% of the country's total hydropower production. Most of the hydropower stations are situated in the south of Sweden, are often small and were constructed between 1880 and 1950. The hydropower plants in the north of Sweden are generally much larger and were built between 1910 and 1970 and often the schemes included construction of very large reservoirs to facilitate power production in the hydropower plants downstream.

Prior to the 1960s little was known about the environmental impacts of hydropower, although it was clear that power stations and dams

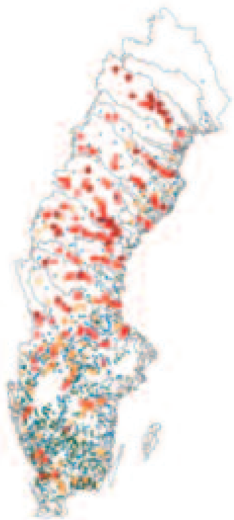


Figure 1. *Hydropower plants in Sweden. Sweden has 2,101 hydropower plants, 206 of which account for 93 percent of the country's hydroelectric power production. The size of the dot indicates the size of the station.*

had a huge impact on the migration of salmon and sea trout to their spawning grounds and several large rivers lost their salmon populations (e.g. Rivers Luleälven, Skellefteälven, Ångermanälven, Indalsälven, Ljusnan, Dalälven and Lagan). However, other impacts on biodiversity had not been studied. The main goal for the society was to support the production of electricity to facilitate industrial development and improve communications and standards of living.

The River Ätran before the hydropower station was built in the upper part of the river (left). The hydropower station and dam (right) located in the upper part of the Atlantic salmon's former habitat. Photo by Björkström and Hans Schiblii.

In Sweden, all hydropower stations require a court decision regulating the conditions for water use. The first water legislation, dating from 1918, was mainly designed to make it easier to obtain a court decision to allow construction of hydropower plants. During the 1960s, the debate increased regarding the dilemma of hydropower production and safeguarding the aquatic environment. Since 1990, more than 30 rivers, or parts of rivers, have been protected from hydropower exploitation as a result of political decisions. In 1983, new water legislation and other environmental legislation was enacted in Sweden which to some extent made it more difficult to obtain permission to build new hydropower plants. The new legislation gave the environmental courts additional powers to specify conditions for the hydropower generation that took greater account of the environment. Since the 1980s, several larger hydropower plants have been built. Hydropower development is influenced by many factors including development of nuclear power plants, environmental interests to protect watercourses from further exploitation and also to some extent the improved water legislation in place since 1983.

The terms imposed by the court for hydropower plants, unlike other industrial activities, are not time-limited. In some cases the court decision includes mandatory building of fishways for upstream

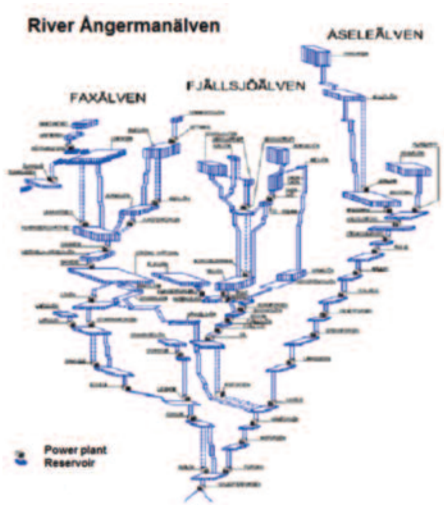


Figure 2. *Schematic map of hydropower plants (black boxes; n=42) and reservoirs (blue boxes) in the Baltic River Ångermanälven. The spawning grounds have been destroyed or made inaccessible. Only one fishway exists. Yearly releases of smolts from hatcheries compensate for part of the lost natural production of salmon and trout.*

migration. If the damage to salmon production is very severe, compensatory releases of salmon smolts from hatcheries has been approved as an alternative mitigation measure.

Renegotiation of terms can be decided by environmental courts at the request of the authorities. However, the authorities are responsible for all legal costs including those of the hydropower companies. As a consequence, few of the old court decisions have been improved; in fact most of the court decisions are according to the law of 1918.

In 2014, a government investigation proposed new environmental legislation, more consistent with the EU Water Framework Directive. This proposed that permits for hydropower plants should be time limited, that the environmental authorities should be able to decide on new terms for the hydropower plants in the same way as for other environmentally damaging industries and that the hydropower plants should bear their own costs for measures to protect the environment. The hydropower industry has strongly criticized this proposal, while the environmental authorities and organisations have endorsed it. The government has not yet decided whether or not to present a proposal for new environmental legislation to the parliament.

Dialogue and national strategy

In 2012, the Swedish Agency for Marine and Water Management was given a government mandate to initiate a dialogue with the relevant authorities and other stakeholders with the aim of building increased consensus on hydropower and the EU objectives for renewable energy and the environmental objectives for biodiversity and water management. One outcome from the dialogue has been a general consensus on which river systems are most important for hydropower production. Another outcome has been a general consensus that the approximately 1,900 smaller hydropower plants, which produce only 7% of the total hydropower production, have a major impact on biodiversity and the technical measures to restore, for example, salmon production can be implemented relatively easily in many of them.

The Swedish Agency for Marine and Water Management and the Swedish Energy Agency have developed a national strategy for enhanced energy production and biodiversity. The strategy identifies where environmental and energy measures should be focused in order to maximize the total value of biodiversity and energy production.

Best Available Technology (BAT) for hydropower generation and other initiatives to improve fish passage

Fish passes are important to maintain biodiversity and restore fish production. As the stocks of Atlantic salmon are often weak, and marine survival is currently low, it is essential that all potential nursery habitat is accessible to salmon and that smolts can migrate freely to the sea. Restricted fish passage can have significant ecological impacts including:

- exclusion of salmon from important nursery habitats;
- increased mortality due to predation by fish and birds, increased exploitation by anglers, and increased parasite burdens as salmon congregate at obstacles and move through impoundments; and
- injury or death of smolts and kelts at spillways and sills or passing through turbines during their downstream migration.

When providing fish passage facilities, the focus is often on ensuring free passage for upstream migration. However, it is also vital to improve conditions for downstream passage, especially in watercourses with hydropower plants.

Both upstream and downstream passage can be achieved in four ways:

- removal of hydropower plants, dams and reservoirs;
- opening of dam or sluice gates;
- natural fishways; and
- technical fishways.

Fish passes should be built to facilitate as easy passage as possible. Fish passes that require high swimming speed and ability must be very short. Where possible, fish passes should also ensure that all species in the river (not only fish) can pass artificial barriers.

Removal of hydropower plants and dams

In the last twenty years, a number of small, old hydropower plants that produce little electricity and old plants requiring costly renovation have been removed in Atlantic salmon rivers in Sweden. Additionally, the requirement to install costly fishways has resulted in removal of dams as a less costly measure. With financial support from the authorities, it has been possible to finance the purchase of such plants or at least the permit for hydropower production and the removal of the migration barrier.

When a dam or other obstacle is removed (which, of course, requires an environmental permit) a passage is created in the existing channel, normally encompassing the whole watercourse. This is, therefore, the solution that works best for most species and most sizes of watercourse. Removing the dam also means that habitat lost to salmon production may again become available. Furthermore, migrating smolts often suffer large mortalities due to predation when passing impoundments.

The work to remove the obstacle is usually followed by work to build up a naturally fast-flowing stretch of river where the obstacle

Before and after removal of a dam at a hydropower plant in the Atlantic salmon river Rolfsån. The dam was replaced with a rocky ramp. Photo by Andreas Bäckstrand previously stood. In general, these measures do not require maintenance and are relatively cheap to implement. The new rapids often become an important habitat for species that live in fast-flowing water.

In the long-term, the cost of removal of a dam can be low compared to the other alternatives. For example, there will be no further costs in maintaining a technical fishway. Normally there is no risk of re-starting hydropower production if the station and the dam have been removed. In several cases, the cost of a technical fishway or a natural fishway can be so high that it is more cost effective to remove the station and the dam.

Opening of dam or sluice gates

A considerable difficulty in removing dams can be the high sediment load from the old impoundment and issues with the stability of the ground particularly where there are buildings near the dam. One possible solution is to retain the dam and open the sluice gates during peak migration periods to facilitate migration of salmon without passage through the turbines. In some situations this approach has been used even where technical fishways or natural fish passes have been built, in particular to allow downstream migration of salmon, trout and eels.

Natural fishways

Three main ways to create natural fishways are used in Sweden:

- rocky ramps to create rapids over the obstacle (see above);
- natural channels bypassing the obstacle within the watercourse (bypass through the dam); and
- natural channels bypassing the obstacle outside of the watercourse (bypass).

These different techniques are often combined:

Rocky ramps, or bottom ramps, are used to raise the water level downstream of the obstacle to migration while still maintaining water levels upstream so that a ramp is created allowing fish passage. This method is often used in smaller watercourses for low head dams.

A bypass through the dam is a natural channel built into the watercourse itself. This is different to an external bypass, which is a channel around the obstacle that is built outside of the existing watercourse. The bypass through the dam can be designed so that it takes a given quantity of water at different levels of water flow. It is suitable for use in situations where the land around the obstacle cannot be used. Since the bypass is built within the watercourse and has a natural substrate bottom, it is easy for migrating species to find and use. It is likely that a bypass through the dam is more effective than a bypass as the attracting water is generally easier to find.

Bypass through the dam in the Atlantic salmon river Rolfsån. Before (left) and after (right). The former technical fishway did not function properly. Photo by Andreas Bäckstrand.

External bypasses are natural passes that are built to divert water around an obstacle. They are normally built with a low gradient (1 - 5%) and a stony littoral zone. Many species can utilise an external bypass. One disadvantage with external bypasses is that they are sensitive to variations in the water level upstream. The external bypass tolerates greater water level variation if the inflow is constructed to regulate the flow of water. External bypasses can be built with natural sections of rapids and can thereby also function as rearing habitat for mussels, fish, insects and other invertebrates.

Bypass in the Atlantic salmon river Rolfsån. Photo by Andreas Bäckstrand.

In order to achieve a low slope in the fishway, external bypasses may have a meandering path, thus increasing their length. The longest external bypass in Sweden was built in 2013 in the Atlantic salmon River Säveån and is 500m long and cost approximately €6million. Thirty years earlier the hydropower station was for sale and the cost was then €300,000.

External bypasses are sensitive to erosion when water seeks a way out through the ground and creates new channels leading more directly down the slope. The bottom in Swedish bypasses is often protected with a sealing layer, e.g. a geotextile.

Technical fishways

In general, technical fishways require special expertise for their construction and they require regular maintenance. In 2002, it was estimated that 11% of the fishways in Atlantic salmon rivers in Sweden did not allow fish passage (Hans Schibli, *personal communication*). Most of these fishways had been constructed many years ago.

In Sweden, nearly all of the hydropower plants were constructed more than fifty years ago when knowledge and interest in fish passage issues was limited. Often it is more difficult and more costly to retrofit fishways at old hydropower plants than if the fishways and hydropower plant were constructed at the same time.

It is very important that the entrance to a fishway is easily located by salmon. This problem is most frequent for downstream migrating smolts or kelts when the water flow into the turbines greatly exceeds that through the fishway. Different types of grids (Figure 3, physical screens) installed upstream of the turbines are often used in smaller rivers in order to direct smolts and kelts towards the fishway. In the

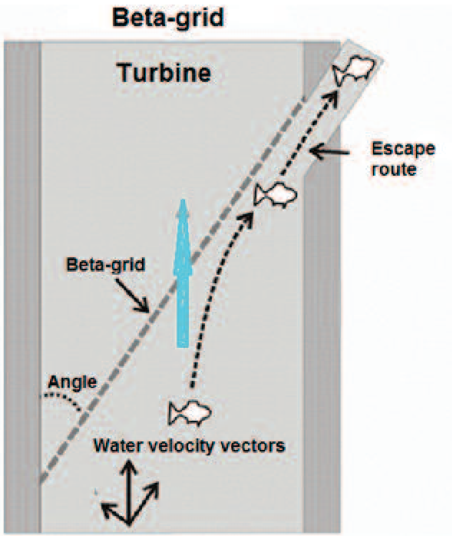


Figure 3. *A beta-grid located upstream of the turbine can direct smolts and kelts into the fishway (Calles et al. 2013).*

largest rivers, trials with systems with trash-racks to direct smolts and kelts to the opening of the fishway have been made with varying results since trees and other objects may block the screens.

Generally three types of technical fishways are used in Sweden or a combination of these types.

The **pool and weir fishway** is the traditional fish ladder. It consists of pools separated by weirs that break the head of water into passable steps.

Pool and weir fishway in the Atlantic salmon River Nissan. Photo by Hans Schiblii

The **vertical slot fishway** typically consists of 30 - 50cm wide vertical slots between pools. The vertical slot has a lower water velocity and turbulence than a pool and weir design. Furthermore, the vertical slot is insensitive to variation in the water level upstream.

The **Denil fishway** is an artificially roughened channel, with baffles pointing upstream extending from the sides. Denil fishways are typically installed at sites with steep gradients (10 - 25%). The fishway itself consists of a relatively narrow flume with U-shaped baffles installed at frequent intervals. It uses more water for its depth and width than any other type of fishway, which is a definite advantage in attracting fish to the entrance. Denil fishways typically require a high degree of operational supervision and maintenance. The fishway must be kept completely free of debris to avoid altering the flow characteristics of the baffles, which would affect fish passage conditions.

Establishing criteria for Best Available Technology in Sweden

Establishing BAT is a joint project of the Swedish Agency for Marine and Water Management, the hydropower industry, County boards and Universities. So far four reports have been published.

The project has focused on:

- fishways;
- technical installations to facilitate environmental flow regulation (not ecoflows as such); and
- maintenance and monitoring.

Fishways and upstream migration

The recommendation is that fishways at artificial dams should allow migration for all species and age groups.

Natural fishways are preferred (e.g. bypass, rocky ramp, fish slope, bypass through the dam). A maximum slope of 5% (extreme 9%) is used unless passage would be difficult for species other than salmon in which case a technical fishway may be installed.

For technical fishways, the vertical slot design is preferred over pool and weir and finally Denil. The design of technical fishways should also allow weak swimming species to pass. The depth in technical fishways should be at least 1m with a flow of $1m^3/s$ for salmon and large sea trout and depth of 0.5m and flow of $0.5m^3/s$ for smaller sea trout and other species. The attraction flow should be 5% of the flow at the site and the fishway entrance should be in a suitable location.

Sluices and elevators are not recommended.

Fishways – downstream migration

Fish larger than 10cm (smolt) should always be screened away from the turbines. Physical screens are preferred over behavioural techniques (electricity, sound, light, bubbles etc).

Beta screens (angled across the river usually at 30^o) are preferred to alpha-screens (angled vertically but aligned perpendicular to the flow) and the least preferred solution is other types of screens (e.g. louvre).

Screens should be installed from the surface all the way to the bottom with 10 - 18cm spacing between the bars.

The flow in the fishway should be at least 2% of the flow at the site.

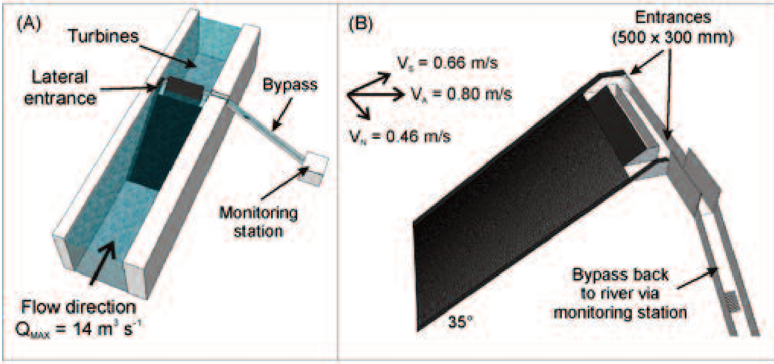


Figure 4. *An alpha-grid upstream from the turbine can direct smolts and kelts into the bypass (Calles et al. 2013). Note that the screen covers the entire depth and width of the channel.*

Technical installations facilitating environmental flow regulation

Automatic regulation of flow at dams is preferred, allowing better monitoring and less pronounced alterations in flow.

The outlets from power plants and dams should allow bottom and surface water of different proportions to be used in order to avoid high temperatures and facilitate sediment transport.

Safety installations are required to avoid loss of water in the river bed due to technical failures.

Examples from Swedish rivers with Atlantic salmon

River Ätran

The River Ätran is the most important salmon river on the Swedish west coast. In 1903, a hydropower plant was built close to the mouth of the river in the city of Falkenberg and later a second hydropower plant was built in the same area. Salmon and sea trout experienced great difficulties in passing the dam using the original fish ladder. In 1946, the dam was equipped with a Denil fishway. Salmon immediately started to use the fishway and the population in the river is now of good status. Salmon parr densities have averaged 98 per $100m^2$ since electrofishing monitoring started in 1959. Data from an installed Vaki counter show that 3,000 - 5,000 Atlantic salmon and sea trout passed the power plant annually from 2000 to 2010.

Although the Denil fishway was functioning well for strong swimmers, such as salmon and sea trout, other species were hindered, among these red listed species including eel (*Anguilla anguilla*) and sea lamprey (*Petromyzon marinus*).

Furthermore, downstream passage of fish has been a problem in the river. Some approaches to reduce the mortality of downstream migrating Atlantic salmon and brown trout have been tested

The Denil fish ladder built in 1946 in the River Ätran. Photo Hans Schibli.

including trash gates and low-sloped fine-spaced racks. Smolts and kelts were radio-tagged and tracked passing the facilities. An open trash gate proved to have a very low efficiency for smolts (7%) and most individuals passed through the racks and turbines. The efficiency was intermediate for kelts (40%) and several individuals died on the trash racks or remained upstream until the end of the study. The route-seeking time was limited for smolts but substantial for kelts. Using surface spill gates and fine-spaced racks the efficiency in directing smolts and kelts has been improved (Ph. D. Olle Calles, University of Karlstad, *personal communication*).

In 2012, the Environment Court granted permission for the removal of Herting dam in the River Ätran. In 2014, part of the dam was removed, opening half of the main stem for free passage of fish and other species. The habitat in this part of the river has been restored and a dam upstream guarantees a minimum flow of 11m^3/s. The older of the two hydropower stations will operate all year round but the newer power station situated in the main stem, which has been opened for fish passage, will only operate during winter high flows.

The dam has been removed (2014) in one of the two main stems in the River Ätran. A construction directs migrating Atlantic salmon into a fish counter situated in the middle of the mainstem.

Concluding remarks

Fishways are never 100% effective so a proportion of the migrating population is lost at each passage. In rivers with multiple passes this can have a substantial negative cumulative effect as too few spawners reach the nursery areas and few smolts reach the sea. Often fish that do pass are delayed and may experience increased mortality.

The low efficiency of fishways is often related to low attraction flows compared to the main flow through the dam or turbines.

Existing fish passes are often not sufficiently well designed to allow species with weak swimming abilities to migrate, resulting in reductions in biodiversity. This has led to a focus on establishing natural fishways instead of technical fishways.

However, several examples exist of fishways that have made access to salmonid nursery areas possible and populations have been sustained by properly working passes.

Careful design, proper maintenance and monitoring of fishway efficiency are crucial to their effectiveness.

Removal of dams should always be prioritised because these solutions enable most aquatic species to pass both up and downstream without delay or mortality. Additionally, an increase in productive habitat for salmon and trout can often be achieved.

Removal of the dams may also result in reduced predation on smolts. In systems with several dams, dam removal is the preferred option compared to other approaches to facilitate fish passage.

The second choice for upstream movement is a natural pass mimicking a natural watercourse. Technical fishways are mainly used for large obstacles such as power station dams, where there is a large fall (head) in the water level.

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Annex 6

CNL(15)44

Measures to improve fish passage in the north-eastern United States including development of performance (survival) standards for fish passage at hydroelectric dams

Introduction

The iconic Atlantic salmon was once abundant in nearly every major river in New England. Today, the State of Maine supports the last remnant populations of anadromous Atlantic salmon (*Salmo salar*) in the United States. In 2000, a suite of populations of Atlantic salmon were recognized as endangered under the Federal Endangered Species Act (ESA); the initial ESA-listing was revised in 2009 to include a wider geographic area (over half the state of Maine) and a greater number of populations. These populations are referred to as the Gulf of Maine Distinct Population Segment (GOM DPS) of Atlantic salmon. The primary objective for the management of Atlantic salmon in the United States is to rebuild the GOM DPS of Atlantic salmon (and the ecosystems upon which they depend) to a point where the protections of the Endangered Species Act are no longer required. The primary threats to endangered Atlantic salmon are low marine survival and dams (NRC, 2004; USOFR, 2009). Given that dams represent a primary threat to the species in the United States, an enhanced strategy to restore connectivity within the freshwater range of the GOM DPS is now well under way.

While removing dams and other barriers results in the greatest restoration of access to habitat (Pess *et al.*, 2014), there are situations in which dams cannot be removed. In these situations, two federal agencies, NOAA's National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (USFWS) work with the dam owners to ensure that the fish passage devices are effective at passing fish. In the United States, several federal statutes relate to the governance of fish and wildlife resources and hydropower dams. Of particular note, Section 18 of the Federal Power Act provides NMFS and USFWS with the authority to require fishways at hydroelectric dams. Further, the ESA requires that any federal agency of the United States must ensure that any action it authorizes, funds, or undertakes does not prevent the survival and recovery of any endangered species.

The Federal Energy Regulatory Commission (FERC) is the lead federal agency that regulates energy generation from hydroelectric projects and would be obliged to comply with the terms of the ESA and the Federal Power Act. Before issuing or revising permits for hydropower dams and operations, FERC must consult with NMFS and USFWS to ensure that dam operations do not negatively impact the survival and recovery of ESA-listed species.

No new main-stem dams have been constructed in Maine since 1989. Since licences of existing dams typically expire every 30 years, the dam owners must consult with FERC (and consequently NMFS and USFWS) to obtain a new licence. These events are opportunities to improve fish passage in most instances. In the past, NMFS and USFWS provided dam owners with design criteria for the construction of fishways. If the fishways ultimately proved to be ineffective at passing fish, there was little recourse available to the agencies.

Recently, NMFS has moved away from designing fish passage devices and instead, has focused on performance criteria that must be achieved to ensure the survival and recovery of the species. This novel approach includes the development of performance (survival) standards at each hydroelectric dam within the freshwater range of the GOM DPS. NMFS also requires that the dam owners monitor whether they are attaining the necessary survival standards, and if the rates are not achieved, to take action to improve passage performance and to ensure that the standards are met. Further, the dam owners must demonstrate, through quantitative monitoring, that they are meeting or exceeding the performance standard for at least three consecutive years in order to continue to operate the dam.

In developing this strategy, we surveyed other examples where recovery programs for endangered or threatened fish were successful in areas where hydroelectric dams were present. After a comprehensive review, we identified a system in use in the Columbia River basin on the Pacific coast of the United States, in which survival performance standards at dams are in use. The approach has been applied there with great effect for a variety of Pacific salmon species (http://www.salmonrecovery.gov/Hydro.aspx) including the critically endangered Snake River Sockeye salmon, which must pass four dams in the Snake River and four dams in the Columbia River. Naturally, the models developed on the west coast were specific to Pacific salmon, and we needed a model that incorporates population dynamics, habitat production, and recovery goals specific to Atlantic salmon. Our model would provide the information that we needed to identify a target survival passage standard for each hydroelectric project that is sufficient to ensure the survival and recovery of

Atlantic salmon.

Dam Impact Analysis Model for Atlantic salmon

In 2013, NMFS' Northeast Fisheries Science Center published the Dam Impact Analysis (DIA) Model (Nieland *et al.*, 2013) and a recent publication in the ICES Journal of Marine Science details an early application in the Penobscot River (Nieland *et al.*, 2015). The DIA Model is a population viability analysis that uses life-history characteristics and estimated passage and survival rates at dams to better understand the impacts of dams on the production potential of Atlantic salmon. In particular, we developed the DIA Model to evaluate upstream and downstream survival standards at hydroelectric dams and ensure that recovery of Atlantic salmon can be achieved. The DIA Model is also flexible enough to conduct several 'optimization' schemes. To date, the optimization analyses have not been used in a management context, but we expect to do so in the very near future. In its simplest application, it can be used to assess the demographic effects of various survival rates and determine the relative effects on recovery prospects over time.

The first application of the DIA model was in the Penobscot River (Figure 1). In 2011, we received a Species Protection Plan from the owners of the four dams (Milford, Stillwater, Orono, and West Enfield) on the lower Penobscot River. The Species Protection Plan proposed to continue to operate the dams with several stringent conservation measures that should result in high levels of downstream smolt survival (96% within 24 hours) and high levels of upstream passage for adults (95% within 48 hours). Given the various conservation measures outlined in the Species Protection Plan, we determined that the continued operations of these four dams would not preclude recovery of Atlantic salmon as long as certain mitigating activities were undertaken. These activities included:

- the removal of the Veazie and Great Works Dams (the two lowermost main-stem dams on the river);
- immediate decommissioning of Howland Dam and the installation of a bypass structure around the dam;
- immediate attainment of downstream survival levels of 96% at the remaining four main-stem dams and immediate attainment of upstream passage rates of 95% at Milford and West Enfield dams;
- sustained improvements in freshwater and marine survival; and

Figure 1. *The Penobscot River, Maine, USA. Freshwater production units are delimited by dams (black bars).*

- continued supplementation by Green Lake National Fish Hatchery (NMFS, 2012; Figure 2).

In the analysis, we refer to the removal of the Veazie and Great Works Dams and the decommissioning of Howland Dam as part of the Penobscot River Restoration Project (PRRP) and to the suite of actions that the dam owner must complete as the Species Protection Plan, which is additive to the PRRP. Our assumptions about the decommissioning of the Howland Dam and the installation of the bypass structure around the dam involve immediate attainment of complete upstream fish passage (100% survival); this is an optimistic assumption which will be rigorously tested as few fishways achieve 100% passage. We believe that this assumption is reasonable, however, because the bypass structure around the dam will provide a

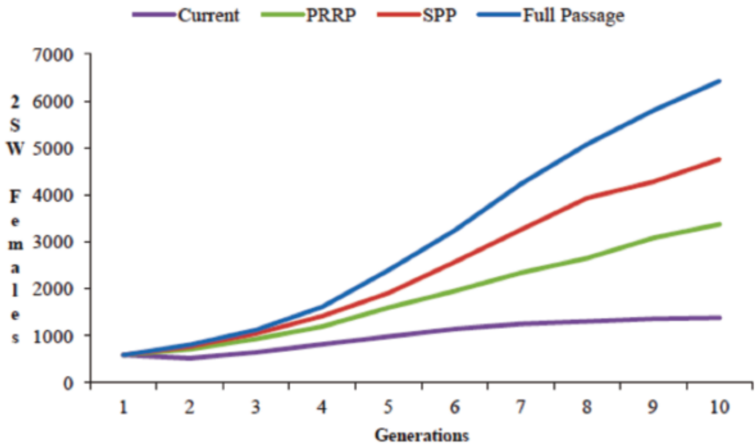

Figure 2. *Projected abundance levels of Atlantic salmon in the Penobscot River with no changes in management ('Current' in purple), implementation of the PRRP ('PRRP' in green), implementation of the PRRP and the provisions of the SPP ('SPP' in red), and complete dam removal ('Full Passage' in blue). 'Current' passage estimates are derived from a variety of empirical studies and modeled survival levels as described by Amaral et al. (2012). These projections assume favorable marine and freshwater survival levels in the future.*

mechanism for the safe passage of all life stages of most fish species around the dam (unlike most technical fishways).

The modeling approach incorporates life stage-specific information, river flow information, and dam mortality impacts to simulate the life cycle of Atlantic salmon in the Penobscot River including:

- fecundity;
- egg to smolt mortality;
- freshwater mortality;
- downstream direct and indirect mortality estimates at dams;
- marine mortality;
- upstream direct and indirect mortality estimates at dams;
- within-river homing and straying rates; and
- hatchery supplementation.

The model is flexible, allowing for changes in all the input variables including the number of dams, upstream and downstream dam passage rates, and other variables. The life-history modeling approach enables incorporation of a wide array of life-history types to accommodate other diadromous species. The model is also being applied to other river systems (e.g. the Kennebec River) to develop performance standards at hydroelectric dams in these systems.

Most model inputs were considered to be random variables, and Monte Carlo sampling from probability density functions was used to create multiple realisations of population trajectories over time. All DIA Model iterations were run for 50 years, roughly ten generations, and 5,000 iterations were run for each simulation. The DIA Model was built in Microsoft Excel with the @Risk add-on.

The DIA Model can be used to compare alternative scenarios of environmental and dam conditions to identify critical parameters and information needs for recovery efforts. The predicted abundance and distribution of adults and number and proportion of smolts killed due to the effects of dams were reported for several modeling scenarios. The DIA Model simulations are not meant to predict absolute abundance, distribution, or mortality, but rather are meant to project the relative changes under different modeling scenarios. The DIA Model revealed that recovery potential of Atlantic salmon is most sensitive to marine and downstream dam passage survival rates.

The DIA Model predicts that the implementation of these survival standards will lead to an improvement in the numbers, reproduction and distribution of Atlantic salmon under similar environmental conditions. This is the case because:

- the proposed performance standards result in an increase in the abundance of pre-spawn adult Atlantic salmon returning to the Penobscot River; and
- the increase in the number of returning Atlantic salmon, due to the improved downstream survival and upstream passage rates at the dams, will lead to increased distribution of Atlantic salmon in the upper Penobscot watershed (i.e. where abundant spawning and rearing habitat exists).

Implementing Performance Standards

When analyzing the impacts of a hydroelectric dam on ESA listed Atlantic salmon, we must consider the effects to the species' abundance, distribution, and reproduction. If the dam appreciably reduces the species' chances for survival and recovery, we are required to develop an alternative (e.g. new fishway, turbine shutdowns and spillage, downstream diversion) that would improve the abundance, distribution, or reproduction of Atlantic salmon in the geographic area impacted by the dam. By requiring the dam owners to meet certain and explicit upstream and downstream survival standards, we have a clear assurance that the project will have minimal impacts on the survival and recovery of Atlantic salmon. These assurances can only truly be delivered when accompanied by a rigorous monitoring and review process. In short, this process uses the adaptive management paradigm to articulate a goal (the performance standard), quantitatively monitor whether or not the goal is attained, review results, and adjust as necessary. An example of an explicit decision process for downstream passage is described in Annex 1.

Unfortunately, 2014 was a very challenging year with adult salmon returns among the lowest on record. Mechanical breakdowns occurred at the lift for the lowest dam on the Penobscot River (at Milford Dam) for a period of approximately two weeks in 2014. This, among other challenges led us to conclude that the dam owner did not achieve its performance standard for upstream passage in 2014. Further, monitoring of downstream passage rates of smolts is as yet inconclusive in terms of documenting whether the performance standards are being achieved. We have advised the dam owner that they did not attain the required performance standard and that further modifications to their operations and monitoring of progress towards attainment of the performance standard are required. As such, we have had extensive discussion with the dam owner and other relevant authorities (e.g. the Maine Department of Marine Resources) in order to assist the dam owner in achieving the performance standards as quickly as possible. To that end, we have recently developed, and are currently implementing, a comprehensive fishway operations and maintenance plan and refinements of study methodologies. We fully expect fish passage evaluations and operations (particularly at Milford Dam) to be greatly improved in 2015 as a result.

Other Protective Measures

It is also important to ensure that once access to important freshwater habitats is restored, that the habitats are capable of supporting all life stages of Atlantic salmon. Thus, the US has several mechanisms to protect, conserve, and enhance habitats for the species. This is primarily achieved under the Magnuson Stevens Fishery and Conservation Act and the ESA. Under the Magnuson Act, habitat necessary for each life stage of Atlantic salmon to complete their life cycle is identified and protected. Under the ESA, critical habitat has been designated for Atlantic salmon that ensures that the habitats that are necessary for the survival and recovery of the species are protected. These designations indicate areas important to Atlantic salmon and inform the public of the need to protect these important areas. The US approach to habitat protection and restoration is consistent with the NASCO Plan of Action for the Application of the Precautionary Approach to the Protection and Restoration of Atlantic Salmon Habitat (see CNL(14)75).

Recognizing that habitat protection is only one part of the equation, the United States equally embraces the need to restore the productive capacity of Atlantic salmon habitat which has been adversely impacted through reduced connectivity caused by dams and improperly designed road crossings. This is accomplished partly through incentive-based programs which provide federal, state and private funds to support dam removal and other fish passage improvements such as the construction of fishways. However, it is important to note that these projects can only be accomplished through partnerships with many jurisdictions and interested parties. Conservation organizations are key partners in salmon protection and recovery in the United States, including working with local governments to put together proposals to seek funding to implement community-based restoration projects. The Penobscot River Restoration Project is the best known of these, but there are many others (recent highlights are summarized in CNL(14)75, CNL(14)33 and CNL(15)32). In addition, representatives from a variety of industries and industry organizations are excellent partners to seek the adoption of protective measures into their business rules and also to implement restoration and recovery projects on their lands, frequently using their equipment and staff (http://sfimaine.org/fin-meetings/).

Future Work Implementing Performance Standards

The Penobscot, Kennebec and Androscoggin Rivers contain a significant amount of valuable habitat for Atlantic salmon in Maine as well as a number of hydroelectric dams. Going forward, we will expand the DIA Model to identify survival standards at all dams in the GOM DPS necessary to protect and recover Atlantic salmon. We are also actively seeking ways to advance adaptive management of fish passage restoration for other sea-run species (e.g., American shad, *Alosa sapidissima*) by applying the DIA Model in Maine and elsewhere. In addition, we are seeking ways to more explicitly link performance standards to measurable recovery criteria for Atlantic salmon in future modeling and regulatory actions. In conclusion, the recent application of a rigorous adaptive management paradigm including the development and implementation of performance standards substantially advances prospects of recovery for endangered Atlantic salmon in the United States.

Acknowledgements

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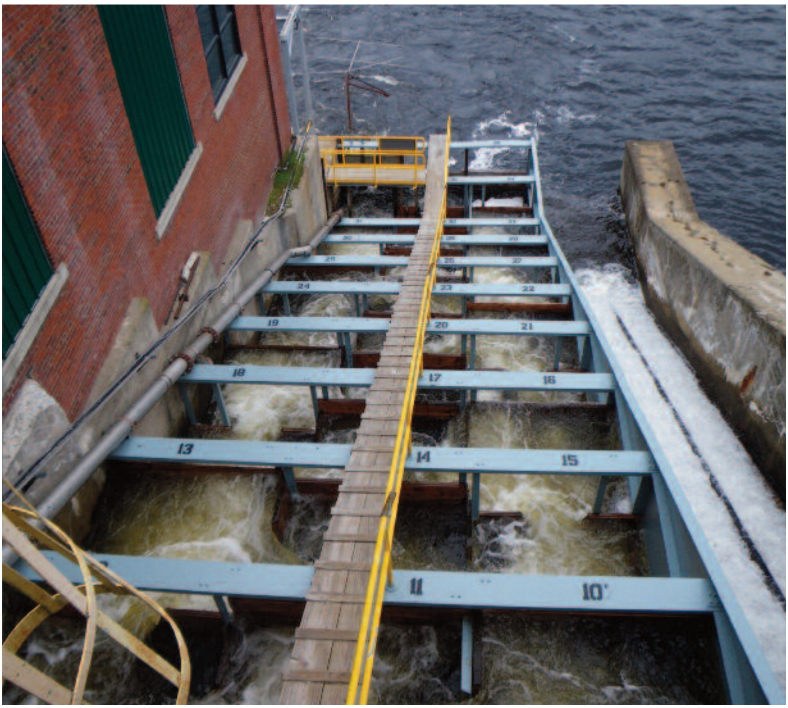
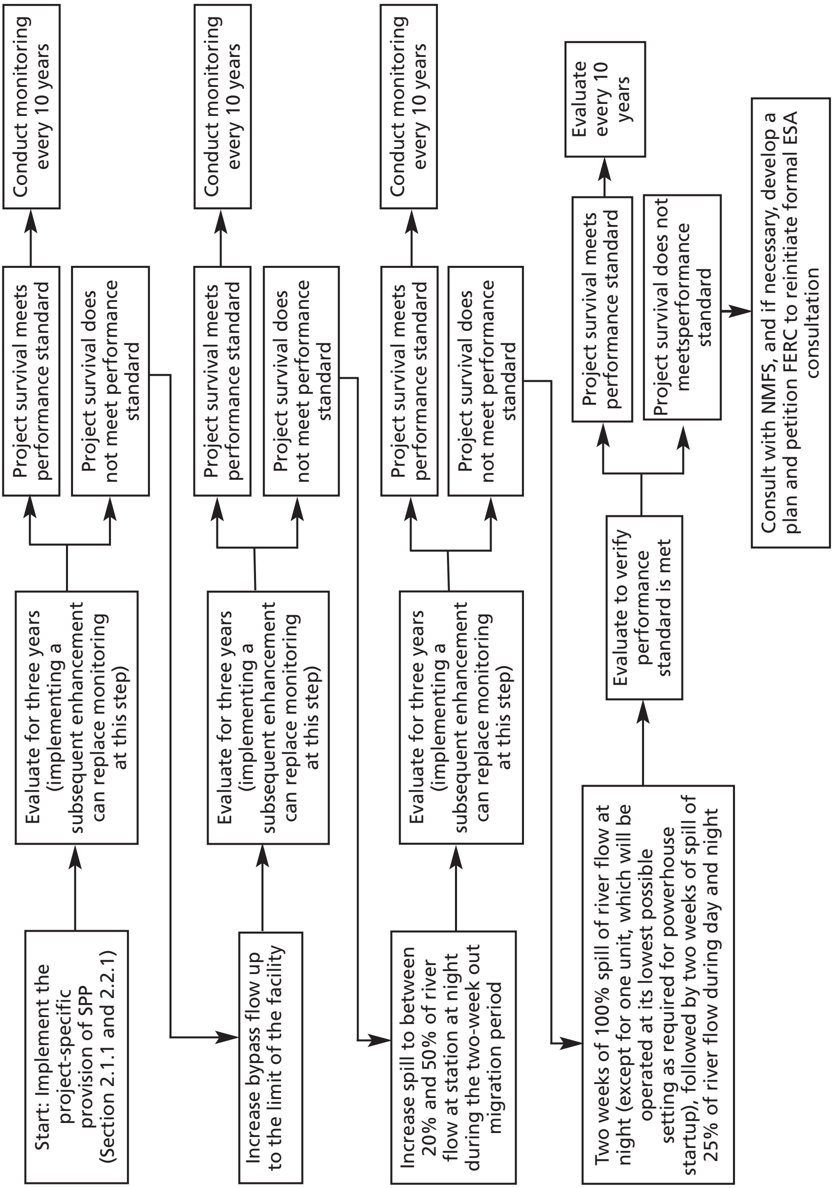


Fish pass at Weldon dam, Penobscot. Courtesy of Jeff Murphy.



Annex 1. *Example of decision process for implementing the downstream performance standard described in the species protection plan for the Penobscot River.*

Annex 7

CNL(15)48

Maintaining and improving river connectivity with particular focus on impacts of hydropower - an NGO Perspective

Following presentations from the Parties on river connectivity with a particular focus on hydropower, this NGO perspective concentrates on river connectivity at a catchment level, looking at other significant issues relevant to free fish passage from headwaters to the ocean and back again, as befits the management of an anadromous species.

Upland Habitat

Healthy juvenile habitat is essential for successful parr production, taking into account that parr can remain in fresh water for between 1 and 5 years and so habitat requirements are permanent, not seasonal. So, potential impacts such as excessive water abstraction can rob upland streams of their lifeblood and, therefore, make survival to smolt stage very challenging.

Downstream Migration

Outward smolt migration is just as important as the return adult journey, but does not always receive the same attention. Various potential barriers can challenge smolts, including weirs and hydropower schemes that delay them and make them vulnerable to predation from other fish species, birds and mammals. In particular, the cumulative effect of multiple barriers can diminish smolt numbers so that the final production of the river can be unnaturally low, regardless of how successful the juvenile stages were.

Aquaculture

There are increasing concerns that freshwater salmonid farming can impact water quality within river systems, especially from excess nutrients such as phosphates, but also from contaminating chemicals, including endocrine disruptors. Some research is being carried out on these issues but much more needs to be done to ensure that migrating salmon smolts, and other aquatic species, are not adversely impacted by freshwater aquaculture discharges.

Open net salmon farming in estuaries, fjords and coastal regions can be the final barrier to outward migration before smolts reach the ocean. Sea lice and disease emanating from farmed fish can transfer to wild salmon and sea trout and cause significant mortality and further reduce the number of smolts that begin their marine phase.

The NGOs believe that the only way to minimise the impact of aquaculture on wild fish is to farm in closed containment units, both fresh water and marine.

Tidal Barrages and low flows into estuaries

Once fish reach estuaries on their return migration, they face two immediate potential barriers to entering rivers; tidal barrages, and low flows either caused naturally by drought conditions or man-made through excessive water abstraction higher up the catchment. Low flows into estuaries are often overlooked in water resource plans as many fail to recognize fisheries issues. This can only be remedied as part of overall catchment plans compiled with political commitment to protecting wild salmon.

Fish Passage

Tidal barrages, weirs, hydropower schemes and high dams all require efficient fish passes of one form or another. Fish passes must have sufficient flow through them to attract salmon to run, preferably at all river levels, as any delay threatens unnaturally high predation. Indeed, shoals of fish detained in estuaries have been shown to decline significantly in number by the day, either being predated or just 'disappearing' from the run. In rivers with an industrial heritage, such as the Tyne in England, residual heavy metal and chemical contamination can also inflict heavy losses on salmon runs when fish have not been attracted quickly enough through the estuary into fresh water.

Land Management and Industry

The freshwater environment is often impacted by poor land management and/or industrial practices, particularly in terms of diffuse pollution from agriculture, road run-off, poorly treated sewage, industrial contamination and the like. Once again, there must be the political commitment to protect salmon and other aquatic species from the impacts of activities that decision makers may consider to be of greater importance than the conservation of fish or the rivers that support them. We hear all too often that the official focus is on 'sustainable development' or 'economic growth'. The NGOs believe it is quite possible to protect river corridors and their dependent species while encouraging economic development and growth, but it does take political commitment and an understanding of the issues. This is not an alien concept and, indeed, it is now increasingly realised that healthy rivers and water quality benefit local communities and economies just as much as salmon and fisheries – and an abundance of salmon is a natural indicator of the health of the entire catchment.

Exploitation by In-river Nets and Rods

Coastal mixed-stock fisheries were discussed at the 2014 Theme-based Special Session and the NGOs urged that these indiscriminate fisheries should be closed because they reflect bad management practice. Once fish enter their natal rivers, it should be up to local management, within the limits of national regulatory measures, whether or not there is a harvestable surplus for nets and rods to exploit, because quite obviously, both netting and angling can cause a significant barrier to fish migrating up rivers. If there is no surplus, then netting stations should be closed and angling should be subject to catch and release, which conserves stocks but still produces economic benefits for local communities.

Spawning and Juvenile Habitat

Once adult salmon reach spawning areas, having negotiated many potential barriers on both their outward and return migrations, the habitat must be in good condition to allow successful spawning and the production of the highest number of healthy, wild smolts as possible. River management practices, such as dredging gravel, or land management issues such as forestry-produced acidification and pesticide chemicals, are possible major impacts at this stage, together with loss of flow due to abstraction, land drainage etc., which is where this presentation began.

Summary

For salmon to survive and prosper, there must be river connectivity and free passage so that the fish can access both their freshwater and marine habitats with as little delay or impact from human interference as possible. We will only achieve the main objective for managers as highlighted at the 2011 Salmon Summit in La Rochelle, of producing the maximum number of healthy wild salmon smolts as possible from river systems, if spawning and juvenile habitats and water quality are pristine.

This depends entirely on political commitment to protecting wild salmon in the face of competing demands for economic development and growth. The NGOs believe that this is not an ‘either/or’ decision, but that imaginative planning can support both economic activities alongside river systems while still protecting the aquatic environment so that salmon thrive in their freshwater stages. That will bring maximum possible benefits to the economy and local communities, while still allowing salmon, perhaps the ultimate indicators of a healthy aquatic environment, to thrive as naturally as possible.

Annex 8

CNL(15)10

Responses from Parties/jurisdictions to the Steering Committee's questions relating to the Theme-based Special Session

1. Describe arrangements in place for consultation and information exchange among relevant agencies and stakeholders in relatio to hydropower developments

Canada

A number of arrangements (e.g. Memorandum of Understanding (MOU), Contracts, Fisheries Management Plans) at the national and regional level have been put in place to address general collaboration, information exchange and the effective operation of hydro developments.

As an example, the Canadian Electricity Association (CEA) and Fisheries and Oceans Canada (DFO), signed a Memorandum of Understanding (Memorandum) in July 2002, which was renewed in 2012 for another three years (2012-2015). The Memorandum commits the parties to collaborate on three themes: legislative and regulatory review; policy development and implementation.

This partnership has enabled a better understanding of the perspectives of industry and aided in obtaining input on policy related to fisheries conservation. The CEA is also interested in the application of the Species at Risk Act and engagement on policy and implementation issues related to aquatic species at risk.

Considerable success has been achieved in developing and implementing operational policies, identifying knowledge gaps, and fostering improved relationships with the Hydro Industry.

The CEA members have valuable in-house expertise on fisheries management and have the capacity to make investments in research and leading-edge technologies to mitigate the impacts of hydroelectric generation on fish and fish habitat, all of which has been valuable in moving forward towards shared goals.

At the local level, CEA member companies also have entered into provincial level MOUs in Nova Scotia and Ontario which have helped to establish priorities for fish protection activities. Additionally, in other eastern provinces, agreements have been developed with individual hydro utilities to improve the operational aspects of hydro developments and reduce their impact to fish populations and habitat. In many instances local fishing organizations and aboriginal groups are involved at some level in the agreements by providing their expertise and resources for specific aspects of the operation.

Denmark (in respect of the Faroe Islands and Greenland)

Faroe Islands

There are a few small rivers with salmon stocks on the Faroe Islands but it should be noted that the rivers did not originally support self-sustaining stocks of salmon. However, commencing in 1947 stocking has been undertaken and the salmon in these rivers are maintained by hatchery releases. In the early 1970s fish passes were constructed over three obstacles in the river Leynará on Streymoy, to improve river connectivity, and salmon fry released further upstream in the system. There are no hydro-electric facilities in any of these rivers and they are small and not suitable for such developments although hydro-electricity is responsible for around 30% of electricity consumption in the Faroe Islands. As indicated in the Implementation Plan for the Faroe Islands there are no threats to salmon habitat in these five rivers.

Greenland

Relevant agencies work closely together, often inter-ministerial working groups and stakeholders can be part of the process. The stakeholders are always heard in the obligatory hearing of plans from the Government of Greenland.

European Union

Denmark

As we do not foresee new hydropower installations and have not had such in a decade, the question is not relevant and we have no such arrangements in place.

Finland

There is no hydropower development in Finnish salmon rivers running to the North Atlantic Ocean. In the Baltic Sea area, the situation is very different in that most of the historical major salmon rivers have been harnessed for hydropower production. The National Fish Passage Strategy was launched in 2012 as a guideline for future R&D projects for restoration of migratory fish populations. The strategy abstract was tabled in the 32^{nd} Annual Meeting of NASCO. In addition, the Regulated Rivers Migratory Fish Forum was established in 2010 to facilitate integration of interests in hydropower production and safeguarding natural production of migratory fish populations. The Forum aims at improving information transfer and interaction between regional development projects, hydropower industries, research institutes and both environment and fishery authorities. Regional plans to improve fish passage are included in management plans for the implementation of the Water Framework Directive targets.

France

The current classification[1] of rivers is the following:

- list 1: no new dam can be authorised and existing dams must ensure ecological continuity at the moment of the renewal of their concession;
- list 2: all dams must ensure ecological continuity, existing dams have five years from when the river is classified to be equipped in order to respect that obligation. New dams can be authorised if they ensure this continuity.

An individual river can be included in both lists. In all cases, ecological continuity at the level of the newly built dam must be guaranteed by appropriate measures in accordance with the results of the impact study.

In June 2010, a commitments agreement for the development of sustainable hydropower in compliance with restoration of the aquatic environment was signed by the following participants: the Ministry for Ecology, Sustainable Development and Energy (MEDDE) and its public agencies (notably ONEMA), associations of local elected representatives most closely involved in hydropower, associations representing owners of French Hydropower, the main French hydropower producers, NGOs, the National Committee for Professional Freshwater Fishing, and the Renewable Energies Liaison Committee (CLER). This agreement was developed within the framework of the National Environment Round Table (the so-called 'Grenelle environment process'[2]). This agreement forms a shared joint platform demonstrating the willingness of each participant to pursue the development of hydropower in combination with stringent environmental requirements contributing to the restoration of aquatic environments. The State is in charge of organizing a monitoring committee for this agreement twice a year, comprising all

[1] *see article L.214-17 of the environmental code for more data.*

[2] *The Grenelle Environment process was a national round table bringing together all stakeholders about environment issues. It was held mainly during 2007-2008. It led to two new laws in 2009 and 2010.*

the signatories in order to establish and share an assessment of its implementation. Two aims have to be achieved under this agreement:

- Development target by 2020: +3TW/hours net per year
- Target for 'good status' by 2015: 66% of water bodies

Germany

Germany's Federal Institute of Hydrology (BFG) and Federal Waterway Engineering and Research Institute (BAW) hold a specialist colloquium every two years where national and international experts present and discuss the latest research findings and study results in the area of ecological continuity. As part of these meetings, all relevant stakeholders including hydropower station operators, environmental organisations and fishery associations share information and expertise. Numerous representatives of the public sector at federal and state level also attend. Further information is available at: www.bafg.de/durchgaengigkeit.

The Forum on Fish Protection and Downstream Fish Migration: The Federal Environment Agency has organised the Forum on Fish Protection and Downstream Fish Migration for the last three years. This forum was explicitly established as a national information and communication platform that revolves around the subject of fish protection and hydropower. Further information is available at: www.forum-fischschutz.de.

In addition to this, a further exchange of specialist information on hydropower use takes place through the Federal Environment Agency (UBA) and Germany's federal states (Länder).

On federal waterways (in the jurisdiction of the German Federal Waterways and Shipping Administration [WSV]): During the actual implementation of measures for upstream migration, the hydropower station operators that are directly affected by the measures are directly contacted by the WSV and informed about the plans and their possible impacts. The hydropower station operators then also receive the opportunity to have their ideas and expectations with regard to fish protection taken into account in the planning activities.

Ireland

There are large-scale high-head hydropower developments in place on four Irish rivers operated by the state owned Electricity Supply Board (ESB). ESB Fisheries Conservation work in various partnership-type research arrangements with many third level institutions (the National University of Ireland, Galway; University College Cork;

Queens University, Belfast), along with the statutory fisheries body (Inland Fisheries Ireland), and other more local stakeholders (angling clubs etc.). The main focus of activity is related to improved upstream and downstream fish passage for salmon and eel although recent activities have focussed upon the movement of sea lamprey and some within catchment movements (trout, perch, pike etc.).

Under Irish Planning law, namely the Planning and Development Act 2000 and the Planning and Development Regulations 2001-2013, prescribed bodies for the purposes of the Act are notified of applications for planning permissions for hydro development. Pre-consultation with relevant stakeholders and authorities is also an integral part of the Scoping Process associated with Environmental Impact Assessments (EIA) as required under (EIA) Directive (2014/52/EU) on the assessment of the effects of certain public and private projects on the environment.

With regard to small-scale hydropower, Inland Fisheries Ireland have developed 'Guidelines on the Construction & Operation of Small-Scale Hydro-Electric Schemes and Fisheries' which sets out guidelines in relation to legislation regarding upstream and downstream fish passage, screening, data to be contained in an EIS for small hydro, compensation flow, etc. While these are Guidelines, it is recommended that the planning authorities who licence hydro developments will adopt these guidelines in their licence conditions.

Spain – Asturias

Environmental consultations are held prior to any project being authorised. The competent authorities assess the potential impact on the ecological connectivity of the river and evaluate the suitability of any corrective measures proposed by the applicant.

Any new project or activity related to the environment must comply with the legislation on environmental impacts, under Law 21/2013, of 9 December on Environmental Impact Assessment, and on species protection, under Law 42/2007 on Natural Heritage and Biodiversity. Different conditions will be imposed on each individual case, taking into account the need to facilitate the movement of migratory species such as salmon, and complying with the legislation relating to environmental or ecological flow-levels as specified in the corresponding current Hydrological Catchment Plan.

Spain – Cantabria

The only consultation between competent authorities and interested parties in the development of hydropower projects take place in the phases of preliminary information or authorisation of the project. In those phase the relevant competent authorities carry out an assessment of the impact on the river ecological connectivity and evaluate the suitability of corrective measures proposed by the company.

Spain – Galicia

Law 21/2013 of 9 December on Environmental Impact Assessment, transposes Directives 2001/42/EC and 2011/92/EC into Spanish law. Hydroelectric plants fall generally within the group of projects which are subject to a simplified environmental impact assessment procedure under this law, except where they affect protected natural areas, Natura 2000 areas as well as areas protected by international instruments, which trigger the ordinary environmental assessment procedure. In handling this type of projects, the competent environmental body consults the public administrations concerned and interested parties prior to the issuing of the environmental impact report. In the event that according to this report, the project must be subject to an environmental impact assessment procedure, a public consultation shall be included for the ordinary environmental assessment. The environmental or the advisory body, as the case may be, make available to the consulted parties the relevant information about the project concerning the environmental assessment, as well as, when applicable, the environmental impact study together with the information obtained from the public information procedure.

Sweden

All hydroelectric power stations must have a court decision regulating the conditions for water use. The first water legislation from 1918 was mostly designed to make it easier to get a court decision on building hydropower plants. During the 1960s the debate increased regarding the dilemma of hydropower production and the aquatic environment. More than 30 rivers or part of rivers have since 1990 been protected from hydropower exploitation due to political decisions. In 1983 Sweden got new water legislation and other environmental legislation which to some extent made it harder to get permissions for building new hydropower plants. The new legislation gave the environmental courts some more possibilities to decide on conditions for the exploitation that took greater account of the environment. Since 1980s quite few larger hydropower plants has been built. This depends on many reasons, as development of nuclear power plants, environmental interests to protect water courses from further exploitation but also partly the improved water legislation from 1983.

The terms imposed in court for hydropower plants, unlike other industrial activities, are not time-limited. In some cases the court decision includes mandatory building of fishways for upstream migration, but only 10% of the hydropower plants have a fishway today. If the damage on the salmon production is very severe, compensatory releases of salmon smolts from hatcheries has been an alternative. On the Swedish west coast such compensatory stocking of reared smolt is undertaken annually at two out of 23 rivers.

Dialogue and national strategy: In 2012 The Swedish Agency for Marine and Water Management got a government mandate to start a continuing dialogue with relevant authorities and other stakeholders with an aim to increase consensus on hydropower and the EU objectives established on renewable energy and environment objectives for biodiversity and water management. An outcome from the dialogue has been a general consensus on in which river systems the hydropower production is most important. Another outcome is a general consensus that the nearly 1,900 smaller hydropower plants, that produce only 7% of the total hydroelectric production, have a major impact on diversity and the technical difficulties to restore for example salmon production can be handled quite easy in many of them.

On a local basis there are several examples on dialogue projects for consultation, information and to start processes with the aim to minimize impact on salmon production from existing waterpower stations. Initiatives can be taken by authorities, companies, NGOs and fishing organizations.

UK (England and Wales)

In meeting its duties, the Environment Agency in England has developed good practice guidance in consultation with the hydropower industry, fisheries interest groups and other environmental regulators including Natural England. A hydropower industry liaison group has been established with whom they meet on a quarterly basis and they regularly engage with fisheries interest groups on hydropower through existing forums such as the Environment Agency's England Fisheries Group.

In Wales, Natural Resources Wales have established a Hydropower Stakeholder Group which consists of representatives from a range of interested parties including the hydropower industry, environmental groups, farmers and land owners, local authorities and Welsh Government. The Group meets three times a year and provides a forum for all representatives to raise any hydropower related issues.

UK (Northern Ireland)

Hydropower developments usually require planning permission (depends on what building works are proposed) but all will require a water abstraction licence from the Northern Ireland Environment Agency (NIEA). For planning applications, all Government Departments are required to provide comments on the proposal and within Department of Culture Arts and Leisure (DCAL) our Technical Assessment Group (TAG) provides the fisheries assessment and advice relating to the planning application. TAG membership includes DCAL, Loughs Agency (LA) and Agri Food and Bio Sciences Institute (AFBI) scientific staff. All applications for water abstraction licences are also considered by TAG and they provide advice to NIEA to put in place the required measures to protect fish stocks. Members of the public can see details of all planning applications submitted and can provide responses to them for consideration by Planning Service. NIEA are required under the legislation to serve notice on the water undertaker, Northern Ireland Water (NIW). NIEA also consult with a number of non-statutory consultees such as DCAL, LA, Natural Environment Division and Rivers Agency. A number of Fishing Associations are also consulted. The application process is currently being reviewed. A group has been set up to review water abstraction application process and guidelines.

UK (Scotland)

Consultation and information exchange among relevant agencies and stakeholders is built into the regulatory framework for controlling risks to the water environment:

- Hydropower developments require prior-authorisation from the Scottish Environment Protection Agency (SEPA) under the Water Environment (Controlled Activities)(Scotland) Regulations 2011;
- Developers are required to provide SEPA with any information it reasonably requires from them to enable it to assess the risk posed by their proposals to the water environment;
- If a proposed hydropower development is likely to have a significant adverse effect on the water environment or on the interests of other users of the water environment, SEPA is

required to consult any other public bodies likely to have an interest in the proposal;

- The 2011 Regulations also enable SEPA to require the developer to advertise such a proposal and thereby provide an opportunity for anyone concerned about the proposal to make representations to SEPA;
- SEPA's normal practice is to require proposals that are likely to have a significant adverse impact to be advertised. SEPA also places details on its website;
- SEPA is required to consider all representations received about a proposal before deciding whether to grant or refuse authorisation;
- SEPA must inform anyone who has made a representation of its proposed decision;
- If a person objects to SEPA's proposed decision, that person can notify Scottish Ministers. If the Scottish Ministers consider it appropriate, they can direct SEPA to refer the proposal to them for a final decision;
- Information on each licence granted is held by SEPA on a public register.

Further details at:
http://www.sepa.org.uk/regulations/water/hydropower/.

The key elements of the regulatory framework for hydropower developments have been developed in consultation with other public bodies and stakeholders:

- SEPA has developed guidance for developers of run-of-river hydropower schemes. The guidance was subject to public consultation and discussion with the hydropower sector;
- Public bodies including SEPA have produced joint guidance on the information required from developers of hydropower schemes;
- Public bodies, including SEPA, and the representative body for hydropower developers in Scotland have developed joint guidance on construction best practice.

Further details at: http://www.sepa.org.uk/media/156800/guidance-for-developers-of-run-of-river-hydropower-schemes.pdf;

http://www.sepa.org.uk/media/34306/guidance-for-applicants-on-supporting-information-requirements-for-hydropower-applications.pdf;

http://www.sepa.org.uk/media/34332/guide-to-hydropower-construction-phase-good-practice-guidance.pdf.

Norway

As part of the decision making process, the proposal for hydropower development is sent to relevant authorities and NGOs on public hearing. There is a large diversity of stakeholders involved in the development of an energy project.

As a general rule, the NVE (Norwegian Water Resources and Energy Directorate) holds consultations and makes information available to stakeholders, and may also organise public meetings etc. as part of the licensing procedure.

Russian Federation

The procedure rules for consultation and information exchange among relevant agencies and stakeholders in relation to capital construction including hydropower developments were established by the order of the Government of the Russian Federation No. 384, 30.04.2013 'Rules for approval by the Federal Agency for Fisheries of capital construction, the introduction of new technological processes and the implementation of other activities affecting aquatic biological resources and their habitats'. The Federal Agency for Fisheries and its regional Directorates are responsible for decision making process on approval of capital construction including hydropower developments. The decision making process is based on analysis of applications made by legal entities, bodies or persons. The application should provide the documentation on planned activities and planned measures for conservation of aquatic biological resources and their habitats. The approval should consist of: 1) description of activities and their impact on aquatic biological resources and their habitats; 2) measures for conservation of aquatic biological resources and their habitats; 3) conditions and restrictions necessary to prevent or reduce the negative impacts on aquatic biological resources and their habitats; 4) conclusions on acceptability of impact of activities on aquatic biological resources and their habitats; 5) comments and recommendations on the finalization of the documentation (if necessary to rework it in terms of the planned measures for the conservation of aquatic biological resources and their habitats).

United States of America

In the United States, the Federal Energy Regulatory Commission (FERC) licenses hydropower developments. There are considerable mechanisms for public consultation built in to the licensing and re-licensing process at dams and other hydropower developments. Since no new mainstem dams have been constructed in Maine since 1989, most consultation activities occur during re-licensing of existing facilities. For the re-licensing process, dam owners must submit a new license application to the FERC. License applications must contain considerable information about the dam (or hydropower development), the watershed, and other uses of the project. FERC makes the new license applications available to the public for review and comment. There is also a process for natural resource agencies to provide comments on the license applications and make recommendations regarding the project's consistency with existing comprehensive fish and wildlife management plans (section 10a of the Federal Power Act).

In the final rule listing Atlantic salmon as endangered in June 2009, the US Fish and Wildlife Service and the National Marine Fisheries Service determined that the FERC relicensing process was inadequate to protect imperilled stocks of Atlantic salmon. Indeed, the inadequacy of existing regulatory mechanisms for dams was one of the primary reasons for listing Atlantic salmon as endangered, because existing regulatory mechanisms (prior to salmon being listed as endangered) did not provide a timely and dependable means to eliminate the effects of dams on salmon and their habitat. Now that Atlantic salmon are endangered and efforts are being undertaken to recover the species, the information exchange among relevant agencies and stakeholders is even greater. A good example is the process by which dam owners must show whether their projects are attaining the necessary survival performance standards at each of their dams within designated critical habitat. Dam owners must be able to clearly demonstrate that the necessary performance standards are being achieved.   The reports provided by the dam owners are scrutinized by a group of fish passage experts (a group chaired by the National Marine Fisheries Service). In instances where this group of experts disagrees with the findings from the dam owners, the National Marine Fisheries Service explains to the dam owners where the findings are inadequate and how they must revise reports, enhance evaluations, and in some cases modify operations that are not achieving the performance standard.

2. *Indicate, briefly, work underway to improve the evidence base relating to fish passage*

Canada

As indicated there are numerous projects across Eastern Canada where fish passage is monitored and assessed. The primary measure to determine the effectiveness of fish passage efforts is ultimately the number of fish that can successfully pass a potential barrier. DFO, provincial fisheries departments, industry, non-governmental organizations and community groups are all involved in monitoring efforts, including conducting fish counts, assessing impacts to fish (e.g. mortality) and identifying fish presence in areas that historically have had extirpated populations. The results are used to improve future developments and mitigation efforts on existing structures.

On 2 February 2010, the Minister of Industry Canada announced the creation of the HydroNet strategic research network, which is funded by the Natural Sciences and Engineering Research Council. DFO is a formal partner to the HydroNet research network. HydroNet is intended to address the potential impacts of hydroelectric generation on fish and fish habitat in fresh water. DFO's Fisheries Protection Program requires scientific advice on the impacts of hydroelectricity in order to make decisions related to the fisheries protection provisions of the Fisheries Act.

Denmark (in respect of the Faroe Islands and Greenland)

Faroe Islands

See response to Question 1.

Greenland

There is no work underway as Greenland does not have any hydropower plants in rivers.

European Union

Denmark

DTU Aqua has carried out a great number of experiments and studies, documenting a suite of passage problems for many species of fish, but do not carry such out anymore due to a general consensus about the need to remove the various barriers.

Finland

The only case in the Atlantic rivers is the River Tuloma, a large transboundary watershed between northern Finland and Russia. An impassable hydroelectric dam is situated on the Russian side, and blocking the migration route of migratory salmonid fish from the Barents Sea to the Finnish territory. There is a project funded by the Finnish Foreign Ministry that promotes the regional co-operation in fisheries issues in the River Tuloma watershed. One of the goals of this project is to make preliminary plans for an EU-ENI neighbour project to make plans for a fish pass at the upper dam in the River Tuloma.

Several activities in the Baltic Sea area are underway to increase biological, economical, technical and social understanding of the systems and their requirements for future development. Research projects have included themes of fish transfers over dams, up- and downstream passage, environmental flow and quality of released fish and means to improve it.

France

After leading the project to draw up an inventory of obstacles to river flow, the national database on river obstacles (ROE), by collating all national data on all rivers in continental France and overseas departments, Onema then managed efforts to develop a national method to evaluate ecological continuity. The goal was to assess the impact of obstacles on the passage of aquatic species and sediment. This vast project, part of the national plan to restore ecological continuity, will identify the installations causing the greatest problems and set priorities for corrective action. Onema coordinated the creation of a standardised national protocol for data collection intended for Onema personnel and other environmental and territorial-development actors in charge of listing the obstacles. The protocol, called ICE (Information on ecological continuity), was developed through a group of national and international scientists (http://www.onema.fr/IMG/EV/publication/ICE/CPA-ICE-Uk.pdf).

Germany

The Federal Institute of Hydrology (BFG) and the Federal Waterway Engineering and Research Institute (BAW) have initiated a research programme on ecological continuity in German waterways. It is intended to identify key factors that determine fish migration corridors and understand how fish move through and orientate in complex hydraulic fields. We will try to understand the influence of dam and fishway geometries on hydraulic flow patterns and estimate effects on fish attraction, entry, passage rates and duration. In the research program the BFG integrate biological with hydraulic methods and conduct laboratory studies in parallel with field work at pilot sites. We use different modelling approaches and test methods for recording fish as well as concepts for the assessment of fish passage efficiency in large rivers. The BFG distinguish between four fields of research: basic principles, attraction, passage and downstream migration. Within the 'basic principles' the BFG focus on swimming capacities and behaviour of fish, characterization of migration corridors, artificial lateral line measurements and evaluation of fishways. Investigations into 'attraction' comprise of fish behaviour in the tailwater, number, position and geometries of entrances, auxiliary water for the attraction flow and number and position of fishways. The topic 'passage' deals with fish behaviour in the fishway, efficiency of different types of fishways, effects of geometric and hydraulic variations and passage of special fishway components (e.g. turning pools). Downstream migration is not the main topic of the programme since not the administration but the water power companies are responsible for the protection of fish at turbines. Here we focus on fish behaviour in the headwaters and downstream migration pathways as well as descent via weirs.

Environmental Research Plan (UFOPLAN): The (current 2015) UFOPLAN issued by the Federal Ministry for the Environment, Nature Conservation, Building and Reactor Safety (BMUB) outlines extensive research and development projects. In the area of fish protection, the Federal Agency for Nature Conservation (BfN) is coordinating a number of activities including a project on the orientation and search behaviour of migrating fish with the aim of improving the size and arrangement of the fish protection facilities in front of hydropower stations. Furthermore there is a research and development project on the 'Evaluation of Measures to Restore Passability Pursuant to Section 35 of the Federal Water Act (WHG)' that has set itself the goal of developing a concept for interdisciplinary research on fish protection and downstream migration facilities, using the example of the hydropower station sites Edersheim/Griesheim am Main.

The German Association for Water, Wastewater and Waste (DWA) is a technical and scientific professional association. It drafts technical standards and brings together experts from municipalities, universities, engineering firms, government agencies and private businesses for this purpose. The specialist committee Ecological Continuity of Running Water Bodies is attached to the central committee Hydraulic Engineering and Hydro Power. Three working groups ('Fish Protection and Downstream Migration Facilities', 'Functional Control of Upstream and Downstream Migration Facilities' and ‘Upstream Migration Facilities’) do preparatory work for the central committee.

Ireland

In relation to the four large-scale hydropower rivers, the ESB have carried out Heisey Turbine tests on their Kaplan turbine to determine the scale of mortality of downstream salmon smolts at each site. Results indicate mortality rates are below 10%. Research is ongoing on the mortality of downstream migrating silver eel through turbines using acoustic telemetry. Mortality is currently estimated at between 19% and 21%. Research is continuing on evaluation of potential alternative hydropower mitigation measures and eel population modelling and analyses of responses of silver eel populations to managed variation in discharge.

With regard to small-scale hydropower, IFI in association with consultants for the turbine operator in Cork City undertook a study to identify impact on salmon smolt passing through the turbine system. Results from this study estimated 7.4% salmon smolt mortality.

Spain – Asturias

There is no such work underway at present.

Spain – Cantabria

There is no such work at the moment.

Spain – Galicia

At present no specific work is being carried out with regard to the crossing of obstacles different from control mechanisms which to some extent may already identify specific accessibility problems for fish species.

Sweden

Establishing best available technology is a joint project of Swedish Agency for Marine and Water Management, the hydropower industry, County boards and Universities. Since the project started in 2012, four reports have been published.

The project has focused on:

- Fishways (both up- and downstream migration)
- Technical installations to facilitate environmental flow regulation (not ecoflows as such)
- Maintenance & monitoring

At the Swedish University of Agriculture two studies are being carried out to evaluate the effect of fishways on the whole fish fauna up- and downstream of a fishway (compilation of data from circa 50 fishways) and to evaluate natural fishways (by-passes) as a new lotic habitat for stream-dwelling fish (compilation of data from circa 60 by-passes).

UK (England and Wales)

Across England and Wales, the Environment Agency has established a geographic database of obstructions, which identified 26,000 obstructions (18,000 of which are man-made) on a river network length of 300,000km. This equates to one obstruction every 11.5kms.

Having established a geographic database, it allows for a much more systematic approach to improving river connectivity and integrating this information into river basin planning including: Water Framework Directive River Basin Plans (and supporting Sea Trout and Salmon Catchment Summaries), Flood Risk Management Plans and Eel Management Plans.

To help optimise the environmental outcomes from improving river connectivity, a matrix has been established to identify super critical and high priority obstructions that seeks to deliver for multiple species (salmonids, coarse fish and eels) and multiple legislative drivers (Habitats Directive, Water Framework Directive and the Salmon and Freshwater Fisheries Act 1975). For England's salmon rivers, 72 obstructions have been identified through this process. Complimenting this, catchment based priority obstructions will be identified for England's principal salmon rivers in partnership with local stakeholders as part of a process of updating Sea Trout and Salmon Catchment Summaries. To help with this, the Environment Agency is developing a phone based app that will enable people to provide information on obstructions in a way that links to the geographic database, which is otherwise known as 'crowd sourcing' data.

Several pieces of targeted research have been commissioned by the Environment Agency examining screening efficiency, weir pools and the potential for cumulative effects and the Environment Agency and Cefas (Centre of Ecology, Fisheries and Aquaculture Science) are working with the Game and Wildlife Conservation Trust to investigate possible impacts of Achimedes hydropower schemes on the behaviour of emigrating salmon and sea trout smolts.

Impact of hydropower on weir pool features: The study found that there was limited impact from on-weir hydropower installations on weir pool habitats. Patterns of velocity and water depth are likely to change but the overall amount of available habitat remains similar at high, medium and low flows. The effect of changing flows on downstream shallow riffles at the weir pool exit was also shown to be limited.

Potential cumulative effects: With an increasing number of hydropower schemes and a concern about whether the effect of individual schemes could be cumulative, the Environment Agency commissioned a literature review and the development of a model to assess the impact of multiple hydropower schemes on salmon.

The literature review showed that multiple schemes have the potential to increase effects, but most of the studies were on overseas sites which were much larger than those typical in England.

The model which tested various scenarios of between 1 to 6 hydropower schemes using hypothetical data based on the Northumberland River Coquet, indicated a range of effects from +18% to -12% of the numbers expected of returning adult salmon. The study found that the variation in effect was highly dependent on the assumed passability of existing barriers, the efficiency of any constructed fish pass, and the location of the scheme on the river with downstream-sited schemes having the potential to cause larger positive or negative effects. Positive effects were always driven by the inclusion of improved fish passage at individual schemes. The study highlights the importance of careful design of schemes and implementation of mitigating measures at individual sites.

Potential effects of Archimedes screw turbines on salmon smolts: The Environment Agency and Cefas are working with the Game and Wildlife Conservation Trust to investigate the effect of a small low-head hydropower scheme on the behaviour of emigrating wild salmon and sea trout smolts on the River Frome in Dorset.

Acoustic transmitters surgically implanted into the peritoneal cavity and submersible acoustic receivers positioned at strategic positions around an Archimedes hydropower scheme and throughout the associated river catchment are being used to monitor the behaviour of emigrating smolts to where the estuary meets the sea. PIT tagged salmon smolts are also being released upstream of the mill to assess impacts. A similar acoustic study is currently being undertaken at a hydropower scheme on the River Ribble. At present the numbers of tracked smolts has been low so the results are inconclusive. The research is ongoing.

The Environment Agency is undertaking a review of existing ecological evidence through a Natural Environment Research Council grant-funded Research Fellowship. This one year fellowship is to enable Dr Gary Bilotta of University of Brighton to assess information the Environment Agency already hold and reach conclusions on the impact of hydropower on fish and invertebrates. This work is due to report in early 2016.

Across Wales, Natural Resources Wales have carried out a monitoring programme at 15 small-scale, high-head run-of-river hydropower sites, taking invertebrate samples in 2014 and 2015. Samples are currently undergoing laboratory analysis. Natural Resources Wales are also currently investigating fish passage at Radyr Weir on the River Taff looking at smolt migration.

UK (Northern Ireland)

A number of scientific investigations into fish passage have been conducted in N Ireland. AFBI/DCAL have undertaken telemetry work to study the movement of adult salmon at natural barriers on the R Bush (Kennedy *et al,* 2013) and at a hydro weir on the Moyola river. The Loughs Agency under the IBIS programme have conducted research into fish migration on the River Foyle and its tributaries and the results will be published. The Environment Agency in the UK makes available its research into issues affecting fish movement and there is regular exchange of information. The NIEA have commissioned a number of river surveys to identify and assess existing barriers with regards to salmonid passage using an assessment tool developed under the SNIFFER project. This information will help to focus enhancement works to improve fish passage in these areas subject to available approvals and budget.

UK (Scotland)

- Work commissioned by SEPA has developed a method for use in evaluating whether man-made obstacles are passable.
- SEPA and partner organisations, in particular the Rivers and Fisheries Trusts for Scotland have been progressively improving information on the location of man-made barriers to migration.
- The information obtained is included in SEPA's state of the water environment assessments, which identify water bodies affected by the impacts of barriers on river continuity for fish.

- Monitoring data collected by SEPA, other public bodies and by fisheries biologists working for fishery managers are used to produce direct assessments of fish status and reported in SEPA's state of the water environment assessments.

Further details at:

http://www.sniffer.org.uk/knowledge-hubs/resilient-catchments/water-framework-directive-and-uktag-co-ordination/fish-obstacles-porosity/;

http://www.sepa.org.uk/environment/water/classification/classification-results/.

Norway

This year a new R&D project for optimizing solutions to reduce loss of fish in power turbines will be initiated. The R&D project, called SafePass (Safe and efficient two-way migration for salmonids and European eel past hydropower structures) aims to find the best solutions for fish migration in regulated rivers, both from the perspectives of the fish and of the energy production.

Russian Federation

Research related to fish passage e.g. in improving fish pass design, understanding impacts of hydropower on fish etc. are conducted by research institutions such as A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences. The results were recently summarized in Pavlov, D.S. and Skorobogatov, M.A. 2014. Fish migrations in regulated rivers. Moscow: KMK Scientific Press. 413 pp. (in Russian). The book analyses and generalizes a large amount of material on biological and hydraulic measures facilitating migrations of fish in rivers of Russia under conditions of regulated flow and flow withdrawal. Main biological, physical and engineering aspects of this complex problem are considered including spawning and downstream migrations of fish, managing their behaviour in water flow; development and application of various fish passing and diversion devices; specific strategies for protection of migratory and resident fish species. General patterns of fish migrations are presented along with basic mechanisms of their migration behaviour (rheoreaction, orientation in the water flow, locomotor characteristics, behaviour in rheogradient and in a heterogeneous flow: turbulence, hydrostatic pressure, water temperature, etc.). Patterns of fish behaviour as they move through dams and in proximity of water intake devices are considered. Downstream migrations and entrainment of juvenile fish in water intakes are considered in detail, analysing the factors affecting these processes, main causes of juvenile fish injury and death during their downstream migration through turbines of hydroelectric power stations. Principles of fish protection, various methods and measures preventing the entrainment of fish in water intakes as well as main principles and strategies for protection of fish populations are discussed. Specific measures and tactics for fish protection under conditions of regulated and withdrawn flow are also considered.

http://www.sevin.ru/laboratories/Pavlov/Pav%206_MFrr_%202014.pdf

United States of America

There is considerable research and monitoring ongoing across the country including important international collaborations. Some highlights of these efforts include:

- The U.S. Fish and Wildlife Service and the National Marine Fisheries Service are developing a document to provide guidelines for dam owners who must achieve a performance standard for Atlantic salmon passage. This document will be completed in 2016.
- The American Fisheries Society's annual meeting provides an excellent venue for researchers and managers to share recent findings concerning fish passage solutions and challenges. In 2015 alone, there are at least six separate symposia at the American Fisheries Society's annual meeting focused on fish passage.
- NOAA's National Marine Fisheries Service, in collaboration with The Nature Conservancy and the Penobscot River Restoration Trust, have invested over two million US dollars to monitor the ecological effects of the Penobscot River Restoration Project.
    - o http://www.penobscotriver.org/content/4097/science-and-monitoring
- A group of scientists is working to synthesize dam removal science nationwide. For more information about the effort:
    - o https://powellcenter.usgs.gov/view-project/526ae54ae4b0be4db9fbf979.
    - o USGS Powell Center Dam Removal Database (http://doi.org/10.5066/F7K935KT)
    - o '1000 dams down and counting' (http://www.sciencemag.org/content/348/6234/496)

For individual dams in Maine within designated critical habitat, each dam owner must study upstream and downstream passage of salmon at their facility in order to demonstrate that the performance standards are being achieved. This process is an open and transparent process whereby dam owners submit studies to the National Marine Fisheries Service who must then review the findings of the study. As with any scientific endeavour, learning opportunities (i.e., improving the evidence base) often come from examples where expectations are not met. For example, there are some instances where performance standards are not achieved, and there is a fairly obvious solution that can be identified (e.g. poor attraction flows). Other challenges are more severe and an obvious solution is not readily available. In these cases, substantial structural modifications to individual dams may be required. Communication and coordination among dam owners and natural resource staff (including biologists and engineers) ensures that the underlying challenges are identified. When they are discovered, they are communicated publicly through the FERC regulatory process (described above). This process is thus enhancing the evidence base regarding the actual levels of fish passage and survival that are being achieved at many dams in Maine.

3. Describe how conservation of productive capacity is taken into account in evaluating options for hydropower developments

Canada

Fisheries Protection Policy Statement (2013)

The Fisheries Protection Policy Statement supports changes made to the Fisheries Act in 2012. These legislative changes focus Fisheries and Oceans Canada's efforts on protecting the productivity of commercial, recreational and Aboriginal fisheries; institute enhanced compliance and protection tools that are enforceable; provide clarity, certainty and consistency of regulatory requirements; and enable enhanced partnerships with stakeholders such as other agencies of government and local groups to ensure a comprehensive approach to fisheries protection.

The intent of the Fisheries Protection Policy Statement is to provide guidance to Canadians to ensure they are complying with the Fisheries Act. It strengthens the Government's ability to address key threats to the productivity and sustainability of our fisheries, such as habitat fragmentation and barriers to fish migration, through standards and guidelines to avoid, mitigate and offset impacts to fisheries and to ensure compliance with these requirements.

Prior to issuing a Subsection 35(2) authorization or a request to provide for fish passage or sufficient flow, the four factors set out in Section 6 of the Fisheries Act must be considered by the Minister. These factors establish a clear structure for the regulatory review process. Therefore, before rendering a decision, the Minister must consider the following:

a. the contribution of the relevant fish to the ongoing productivity of commercial, recreational or Aboriginal fisheries: the role of the fish and fish habitat affected by the project in the overall productivity of the commercial, recreational or Aboriginal fishery;

b. fisheries management objectives: the fisheries management objectives established by federal, provincial, territorial fishery managers or by wildlife co-management boards;

c. whether there are measures and standards to avoid, mitigate or offset serious harm to fish that are part of a commercial, recreational or Aboriginal fishery, or that support such a fishery: the impacts of the development and whether measures and standards have been applied by proponents to avoid, mitigate or offset those impacts that results from their projects. These three factors establish a hierarchy of measures where efforts should be made to avoid impacts first. When avoidance is not possible, then efforts should be made to mitigate impacts caused by the project in question. After these actions, any residual impacts would normally require authorization and should then be addressed by offsetting;

d. the public interest: in most cases, the public's interest in the resource will be served through the consideration of the first three factors: a) the contribution of relevant fish; b) fisheries management objectives; and c) measures and standards to avoid, mitigate or offset serious harm to fish.

In doing so the decisions of the Minister are able to respect the purpose of Section 6 of the Fisheries Act outlined in section 6.1, which states: *the purpose of section 6, and of the provisions set out in that section, is to provide for the sustainability and ongoing productivity of commercial, recreational and Aboriginal fisheries.*

Denmark (in respect of the Faroe Islands and Greenland)

Faroe Islands

See response to Question 1.

Greenland

As there are no hydropower plants in rivers in Greenland this is not an issue.

European Union

Denmark

Not relevant

Finland

Production capacity of each regulated river on the Baltic Sea area has been assessed using basic information on habitat quality and quantity, taking into account river connectivity in different areas. In addition, the probabilistic population modelling tools and parameter values estimated by those, used for the ICES assessment of the Baltic salmon populations, has been used for estimating the number of spawners needed to pass the dams and reproduce in the production areas. The Baltic population model has also been used in evaluations of the historical court decisions on levels of compensation for the loss of natural production in some of the largest regulated rivers.

France

The goal of the commitment agreement signed in June 2010 is to facilitate the assessment of development permit applications and to share a common approach and vocabulary for the development of small hydroelectric projects with due respect to the environment.

A guide[3] brings essential aspects for the drafting of development projects from these two perspectives to the attention of the key players in the hydroelectric sector. It highlights essential aspects for the study of the impact of projects on the aquatic habitat which will be affected. This is a crucial phase, albeit often repeated, for the successful achievement of a project. The quality of input to this phase will have considerable impact on the speed and fluidity of the decision-making process.

The guide emphasises the need to establish a dialogue with the local government authority right at the start of the project evaluation process, as this must be based on careful consideration of the balance between the drive to generate energy and the protection of natural habitats.

[3] *http://www.france-hydro-electricite.fr/fichiers/adherents/Publications%20France%20Hydro%20Electricite/Publications%20autres/2011%20Towards%20the%20hydroelectric%20plant%20of%20the%2021st%20century.pdf*

Concomitantly, there is a document database called 'RefMADI'[4] which is a technical tool for instructor's services to facilitate technical analysis on new hydropower folders. It is intended to guide water management actors (project owners, consultants etc.) on the implementation plan. This documents database is a set of sheets and technical notes organized by file type and by type of operation.

Germany

Any plans that could severely affect a Special Area of Conservation (Habitats Directive) must undergo a Habitats Directive Assessment. In light of the fact that nearly all spawning habitats of the Atlantic salmon are located in Natura 2000 areas and the salmon is a species that is listed in Annex II of the Habitats Directive, plans - such as plans to increase hydropower in a Natura 2000 area, for example - must undergo a Habitats Directive Assessment. For this reason, when plans foresee implementing measures in Natura 2000 areas where salmon are found, a Habitats Directive Assessment generally has to be conducted to determine the effects that the planned measures would have on the salmon's spawning habitats as well.

Ireland

There are no plans to increase the number of salmon rivers (currently four rivers) where large-scale high-head hydropower generation is undertaken.

With regard to small-scale hydropower, the Guidelines in place set out guidelines on the location of new small-scale hydroschemes which may be considered suitable, e.g. locations upstream of impassable falls, high-head locations at rapids/falls where upstream migration exists, low head schemes where there is an existing weir/millrace, provided certain criteria are met. The guidelines also set out locations considered unsuitable for siting of small-scale hydroschemes due to the potential for impact of migration and productive capacity.

Spain – Asturias

We are not aware of any information which suggests a loss of productive capacity linked to the existing hydro-electric structures. All possible adaptations have been made in this respect, such as screens and ladders.

Spain – Cantabria

We are not aware of any data showing losses of productive capacity linked to hydropower installations. However, all possible measures are

[4] *http://www.onema.fr/RefMADI-Hydroelec; http://www.onema.fr/IMG/pdf/RefMadi_maq_v5.pdf (French)*

put in place to limit such loss.

Spain – Galicia

The environmental assessment legislation has not specified the criteria which must be taken into account in choosing between the various options put forward and does not refer to specific parameters, such as the productive capacity of rivers. It is the sponsor who should submit various options and justify the choice of one of them. The competent authorities for nature conservation should take into account the potential impact on the productive capacity of rivers, although their evaluation in practice only refer to aspects that are indirectly linked to the productive capacity and that are referred to in sectorial legislation on river fisheries (ecological flows, devices for postage (ladders and steps) and interdiction (fencing) devices), but it does not directly refer to the productive capacity of the aquatic environment.

Sweden

Unfortunately, conservation of productive capacity in most cases has been compensated by releases of reared smolts. Presently, this method is not endorsed but the majority of court decisions on hydropower activities are based on older legislation and practices. Today such compensation with stocked fish would not be accepted, but all the old court decisions are still valid as the terms imposed for the hydropower development are not time based. The government and regional authorities have the opportunity to apply for improved, new terms for the operation of existing power plants, but this is a time consuming and expensive task and the outcome is uncertain.

If a new power plant was planned for a river with anadromous fish there are now methods developed to identify essential habitats and their capacity to produce salmon and sea trout. If such a new installation was approved it would be with sufficient fishways, both up- and downstream, and with screens to avoid downstream passage through turbines. The primary choice for upstream movement is a natural passage mimicking a natural watercourse. Technical fishways are only used for large obstacles such as power station dams, where there is a large fall in the water level.

UK (England and Wales)

In England productive capacity is protected through the Environment Agency's regulation of hydropower and adherence to its 'Guidance for run-of-river hydropower development' published in January 2014.

Productive capacity is protected through compliance with the Environment Agency's technical guidance on: flow and abstraction management; geomorphology (including weir pools); fish screening requirements; fish passage; Water Framework Directive, nature conservation and heritage; and flood risk.

To protect flows and maintain and improve river connectivity, four tests have been developed to ensure that hydropower developments do not have unacceptable impacts: (1) Must not prevent the achievement of Water Framework Directive objectives at water body level; (2) Must maintain or improve fish passage and fisheries; (3) Must not have unacceptable impacts on protected sites or species; and (4) Must not have unacceptable impacts on the rights of other water users.

The hydropower guidance is designed to protect the salmon resource and preserve the environments in which it lives, which aligns with NASCO's precautionary approach (NASCO CNL(04)57) and NASCO Guidelines for the Protection, Restoration and Enhancement of Atlantic Salmon Habitat (NASCO 2010).

In Wales, Natural Resources Wales protect productive capacity by application of our Hydropower Guidance, in particular Hydropower Guidance Note 2: 'Flow standards to ensure appropriate levels of abstraction are permitted that protect flows and habitat in reaches depleted by hydropower'. Our guidance uses three main management zones: Zone 1 Designated sites, protected species and supporting habitat; Zone 2 lowland and low gradient rivers; and finally Zone 3 for steep upland stream and rivers. The level of flow mitigation is higher for Zones 1 and 2 in which salmon are more prevalent and less so for Zone 3 with greater proximity to the source. As with the Environment Agency our guidance is designed to protect salmon and its habitat. Wales has a high number of riverine Special Areas of Conservation in which salmon is a protected feature. The mobility of the salmon means that many tributaries of these SACs are 'supporting habitat' for the SAC species and within our guidance this requires a higher level of flow protection than other sites.

UK (Northern Ireland)

Productive capacity is not taken into account in evaluating options for hydro development. Under Fisheries legislation fish passage must be provided and the amount of compensation flow for hydro schemes set for all rivers.

UK (Scotland)

All hydropower developments are required to put in place mitigation to avoid or minimise impacts on fish populations:

- Before deciding whether to authorise a hydropower development, SEPA is required to assess the risk posed to the water environment, including to the status of fish populations;
- All hydropower developments are required to provide for fish passage, including protecting against fish entrainment in turbines;
- All hydropower developments are required to provide flows downstream of their abstraction intakes designed to limit impacts on the productivity of the affected stretch of river;
- The mitigation expected for run-of-river schemes is published in SEPA guidance and is included as conditions of any authorisation granted;
- Cumulative risks from small hydropower developments are managed by locational requirements. SEPA provides a web-based screening tool to assist developers in assessing their proposals against these requirements.

Further details at:

http://www.sepa.org.uk/media/156800/guidance-for-developers-of-run-of-river-hydropower-schemes.pdf

https://forms.sepa.org.uk/site/scripts/xforms_form.php?formID=48&returnURL=/

Norway

Environmental concerns are high when hydropower projects are considered. When the environmental values (e.g. a population of Atlantic salmon) is important the project may be rejected, or adjusted to minimize the reduction of the productive capacity. Mitigation measures (e.g. habitat improvements) are given as part of the license to reduce negative impacts on productive capacity.

Russian Federation

The measures for conservation of productive capacity in evaluating options for hydropower developments are outlined by the order of the Government of the Russian Federation No. 380, 29.04.2013 'Measures for conservation of aquatic biological resources and their habitats'. The measures in relation to hydropower developments include 1) evaluation of the impact of planned activities on biological resources and their habitats; 2) construction of fish protection structures and fish passes; 3) setting conditions and limitations for the proposed activity needed to prevent and mitigate the negative impacts on biological resources and their habitats; 4) determining the effects of the negative impact of a proposed activity on the status of biological resources and their habitats and development of measures to mitigate the negative impact; 5) implementing measures to eliminate the consequences of the negative impact on the biological resources and their habitat through stocking, introductions and transfers, fisheries melioration of waterbodies.

United States of America

In setting performance standards for dams within designated critical habitat, the productive capacity of habitats upstream and downstream of a given dam are factored into the modelling efforts. In short, the productive capacity of all accessible habitat upstream of a dam is estimated. The dam impact analysis model (see CNL(15)44) evaluates the relative reductions in productive capacity (i.e. the dam's impact on numbers, distribution, and reproduction) of that habitat at various upstream and downstream passage rates. NMFS must then evaluate any reductions in the productive capacity of the habitat against the statutory definitions of 'adverse modification' of federally designated critical habitat and 'jeopardy' (i.e. impacts to survival and recovery) of the species under the appropriate provisions of the US Endangered Species Act. Thus, these evaluations are directly linked to the productive capacity of the habitat.

4. Where hydropower developments are approved, on the basis of overriding socio-economic factors, describe how any losses of productive capacity are minimized and compensation or mitigation measures agreed so that there is no net loss of productive capacity

Canada

When considering an application for an authorization such as the issuance of a Subsection 35(2) authorization or a request to provide for fish passage or sufficient flow, the Minister must consider the impacts of the development and whether measures and standards have been applied by proponents to avoid, mitigate or offset those impacts that results from their projects. The Fisheries Productivity Investment Policy, A Proponent's Guide to Offsetting (2013) further describes how avoidance, mitigation and offsetting measures establish a hierarchy of measures where efforts should be made to avoid impacts first; when avoidance is not possible, then efforts should be made to mitigate impacts caused by the project in question; after these actions any residual impacts are then addressed by offsetting scaled proportionally to benefit the specific fish populations in the geographic areas impacted by the project or activity.

Denmark (in respect of the Faroe Islands and Greenland)

Faroe Islands

See response to Question 1.

Greenland

As there are no hydropower plants in rivers in Greenland this is not an issue.

European Union

Denmark

With hydropower and any other installations, including a dam or weir, there will be a net loss of productive capacity. Formerly, this was mitigated by compensatory stocking of juveniles (smolts), but this is now only done in very few rivers, where the barriers have not yet been fully removed.

Finland

No such cases on the Atlantic side, and no contemporary cases on the Baltic side either. Principles for such procedures are described in the National Fish Passage Strategy.

France

Hydropower development nearly always results in loss of productive capacity even if compensatory measures are decided in the court. Loss of productive habitat capacity is normally minimised by:

- Installation of fishways for upstream and downstream migration;
- Environmental flow regulation (minimum biological flow level etc);
- partial compensation of loss of productive areas at the site for the hydropower station by habitat restoration in other parts of the river or the watershed system.

Germany

At present, permits for the construction of new hydropower stations are seldom issued. For example, it is prohibited to issue a permit for the construction of new hydropower stations or obstacles to migration in salmon project waters in the Rhine river basin.

In the event that permits for measures to expand hydropower capacity are issued, the environmental impact of these measures is assessed and, if necessary, the issue of the permit is made conditional upon the implementation of compensation measures. But the compensation measures do not necessarily have to be linked to an improvement or increase in spawning habitats for salmon.

The issue of permits for hydropower stations and the implementation of compensation measures are governed by state-level (Land) legislation and can vary from state to state.

Ireland

On the four rivers with large-scale hydropower generation, juvenile salmon stocking programmes are ongoing to compensate for hydropower impacts and smolt generation protocols are undertaken during the smolt run involving either night-time generation and/or spillage to induce downward smolt migration whilst ensuring a lowest level of mortality.

On rivers with small-scale hydropower, mitigation has taken place in some locations (e.g. Crana, Eske) where fish passage improvements have been carried out on tributaries to mitigate for any loss due to hydro and through removal of impasse on falls.

Generation protocols have also been introduced to limit impacts on inward migrations e.g. Lee River, (Waterpower Limited), where generation is not permitted during the months of June & July to allow the main run of salmon past the turbines located at the top of the Lee estuary. Generally for small-scale hydro developments, the guidelines document is used to try and minimize losses of productive capacity rather than any compensation or mitigation measures being agreed.

Spain – Asturias

The preventative and corrective measures are those provided for in the relevant legislation in relation to the installation of fish passes and screens.

Spain – Cantabria

Preventive and corrective measures are those that are recognised by the legislation, regarding installations of fish passages and grids.

Spain – Galicia

There are no specific rules or methodological guides to address these aspects in a coherent manner. The existing rules merely provide that such measures should be integrated, where appropriate, into the environmental impact statement, by replacing, amending or implementing the proposals of the developer. However it should be stressed that the impact on the productive capacity is not addressed directly in these studies.

Sweden

Hydropower development results nearly always in loss of productive capacity even if compensatory measures are decided in the court.

Loss of productive capacity is in recent years normally minimised by:

- Installation of fishways for upstream and downstream migration.
- Environmental flow regulation.
- Loss of productive areas at the site for the hydropower station can partly be compensated by habitat restoration in other parts of the river system.
- Compensatory releases of reared salmon smolt are presently very seldom decided in court as a compensatory measure.

UK (England and Wales)

To date the Environment Agency has not approved an application for a run-of-river hydropower scheme that significantly impacts on productive capacity. No applicant has yet required us to assess their case for allowing deterioration of a water body due to overriding public interest, under article 4.7 of the Water Framework Directive.

Natural Resources Wales too, has not issued a licence on the basis of over-riding public interest.

UK (Northern Ireland)

One hydropower scheme has had an Article 4.7 undertaken, but the scheme is not yet operational.

UK (Scotland)

No response provided.

Norway

Loss of fish productive capacity may be reduced by minimum flow and different kinds of time- and situation-dependent flow regulation.

Other mitigation measures are restoration of salmon habitats, building of fish passes and release of hatchery-reared fish.

Russian Federation

Compensation or mitigation measures agreed in accordance with the order of the Government of the Russian Federation No. 380, 29.04.2013 'Measures for conservation of aquatic biological resources and their habitats'. Compensation and mitigation measures based on stocking, introductions and transfers, fisheries melioration of water bodies. The amount of required work and funds is calculated in accordance with the procedures established by the order of the Federal Agency for Fisheries No. 1166, 25.11.2011 'Methods for calculation of losses caused to aquatic biological resources'. Stocking is conducted in accordance with the item 45 of the Federal Law No. 166-FZ, 20.12.2004 'On fisheries and conservation of aquatic biological resources' and in accordance with the order of the Government of the Russian Federation No. 99, 12.02.2014 'Rules for stocking of aquatic biological resources'. Introductions and transfers is conducted in accordance with the item 46 of the Federal Law No. 166-FZ, 20.12.2004 'On fisheries and conservation of aquatic biological resources'. Melioration of water bodies is conducted in accordance with the item 44 of the Federal Law No. 166-FZ, 20.12.2004 'On fisheries and conservation of aquatic biological resources' and in accordance with the order of the Ministry for Agriculture No. 530, 26.12.2014 'The procedure rules for the fisheries melioration of water bodies'.

United States of America

When analysing the impacts of a hydroelectric dam on endangered Atlantic salmon, we (the National Marine Fisheries Service) must consider the effects to the species' abundance, distribution, and reproduction. If the dam appreciably reduces the species' chances for survival and recovery, we are required to develop an alternative (e.g. new fishway, turbine shutdowns and spillage, downstream diversion) that would improve the abundance, distribution, or reproduction of Atlantic salmon in the geographic area impacted by the dam. By requiring the dam owners to meet certain and explicit upstream and downstream survival standards, we have a clear assurance that the project will have minimal impacts on the survival and recovery of Atlantic salmon. These assurances can only truly be delivered when accompanied by a rigorous monitoring and review process. In short, this process uses the adaptive management paradigm to articulate a goal (the performance standard), quantitatively monitor whether or not the goal is attained, review results, and adjust as necessary.

Further, the United States' Annual Progress Report on actions under its Implementation Plan includes four actions that are specifically designed to minimize or otherwise offset any loss to productive capacity. Of particular note are Actions H1 (which describes highlights of barrier removals) and H4 (which describes activities associated with regulatory review of all Federal actions pursuant to section 7 of the Endangered Species Act which includes activities related to hydropower dams).

5. Highlight any examples of initiatives to improve fish passage, with particular reference to hydropower developments, which involve collaboration between governments and other stakeholders.

Canada

1. Atlantic Salmon Restoration for Rattling Brook – Norris Arm, NL

Starting in the 1990s, there was interest by a local development committee (Norris Arm and Area Economic Development Committee) in restoring salmon to a system (i.e. restocking), on Rattling Brook - where hydropower operations since the 1950s had extirpated the Atlantic salmon run in most of this system. In 2008 a working group of DFO and Newfoundland Power representatives, was established to develop feasible means of reintroducing Atlantic salmon. In February of 2010 DFO issued a S. 20/22 Order (i.e. Directive) under the Fisheries Act to Newfoundland Power to provide flows and passage around its hydroelectric facilities on Rattling Brook to assist in the reintroduction of Atlantic salmon. This required the development of minimum flow agreements and fish passage requirements with Newfoundland Power, to ensure upstream and downstream fish passage is maintained.

The project was initiated in 2013 and involves the provision of upstream passage of adult salmon through a fish transfer facility, and downstream passage of smolt and kelt through passage structures that operate in the spring.

DFO and Newfoundland Power also worked closely with the Norris Arm and Area Economic Development Committee to develop options for restoration of salmon stocks in Rattling Brook. This has resulted in the Committee implementing a program to restock the upper tributaries using adult salmon from an adjacent river.

Year three of the program (2015) has proven to be successful, with over 200 adult salmon returning to the river through the upstream fish passage facility, over 200 adult fish transferred from an adjacent system and young salmon utilizing the downstream passage structures.

2. Atlantic Salmon Restoration for Exploits River – Grand Falls, NL

Abitibi Consolidated, the original owner, operated hydroelectric generation facilities on the Exploits River since the early 1900s. Nalcor Energy (provincial crown corporation) has been operating the facilities since 2009.

The Exploits River originally had few Atlantic salmon because of natural rapids at Bishop's Falls and especially the large falls at Grand Falls. Prior to restoration efforts, less than 10% of the entire watershed was accessible to salmon due to the presence of these natural obstructions (and the hydroelectric facilities built at them).

In the early 1980s the community based Environmental Resources Management Association (ERMA) was formed which worked with DFO to initiate salmon enhancement on the Exploits River. This initiative included installation of fishways (by DFO or Abitibi depending on the site) for upstream migration of salmon, as well as a program to stock headwater areas. In addition, a Salmon Interpretation Center was established on the site of the main fishway to promote public education and awareness. Abitibi and later Nalcor worked extensively with DFO to implement diversions for smolt and kelt around power plant intakes, and to implement minimum flows to maintain fish passage and habitat.

This initiative has seen the natural adult Atlantic salmon run on the Exploits River grow from around 1,200 to an average annual adult incoming run of around 30,000 Atlantic salmon.

Note: Additional examples have been included in the presentation made by Canada at the 2015 NASCO Annual Meeting and its accompanying paper.

Denmark (in respect of the Faroe Islands and Greenland)

Faroe Islands

See response to Question 1.

Greenland

As there are no hydropower plants in rivers in Greenland this is not an issue.

European Union

Denmark

In the last decade, several hydropower stations have been decommissioned and the dams have been breached. This is the case for Vilholt, Karlsgårde, Harteværket and Papirfabrikken. Remaining functioning important hydropower stations are Tange and Holstebro. One station (Vestbirk) is still in place, but no longer operational and will be removed soon. Thus, the collaborations going on between stakeholders are focused on removing the remaining stations and the dams. Post removal evaluations have demonstrated substantial benefit for migratory fish stocks as well as for recreational value of upstream areas.

Finland

See point 1, description of the Regulated Rivers Migratory Fish Forum.

France

Exemplary dam removal and restoration of the natural environment on the Sélune: The two dams on the Sélune - Vezins and la Roche qui boit could not be passed by migratory fish, especially salmon. Since it was technically complex to install fish passes and because the majority of the spawning grounds were located in the actual Vezins reservoir, the State followed the advice of the Sélune local water committee and decided not to renew administrative licences for the two plants which expired in late 2007.

It was, therefore, decided to carry out an exemplary operation to restore the natural environment of the sites by removing the two dams and to treat problematic sedimentation using the different methods currently available. This major project will be the responsibility of the Prefect of the Manche department who will be assisted by a steering committee representing all the stakeholders involved and a scientific council.

The renewal of the concession for the Poutès dam on the Allier river in the Haute-Loire department will be based on an approach aiming for excellence in the Haute-Loire region and will be an exemplary illustration of how energy interests and biological constraints can be reconciled within the framework of regional initiative land planning. After numerous exchanges on the subject, the parties note their disagreement over the relative impact of the Poutès dam on the worrying reduction in the salmon population and take note that the future of this dam could not be incorporated into this agreement.

However the State is informing the stakeholders that it has asked the concessionaire to study an alternative to the current dam which would preserve almost the entire hydroelectric generation capacity whilst facilitating salmon migration. Work is underway.

Both of these examples are fully detailed in https://vimeo.com/97519786.

More actions can be viewed at http://www.onema.fr/IMG/EV/cat7a-rex2014.html.

Germany

Nation-wide prioritisation plan for maintaining and restoring ecological continuity on federal waterways (this concerns approximately 250 sites) issued by the (then) Federal Ministry of Transport, Building and Urban Affairs. The focus of the German Federal Waterways and Shipping Administration (WSV) (which is responsible, pursuant to the Federal Water Act, for ensuring ecological continuity at the transverse structures which it operates or has erected) is on establishing upstream and downstream ecological continuity for fish at sites without hydropower stations. The hydropower station operators are responsible for the downstream passage of fish at sites with a hydropower station.

Measures undertaken by Germany's federal states (Länder) that are documented in the current background documentation for the 2015 management plans for the implementation of the Water Framework Directive targets.

The Forum on Fish Protection and Downstream Fish Migration that was established at the initiative of the Federal Environment Agency (UBA) and is financed by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) (see www.forum-fischschutz.de; see also Question 1, point 2).

Here, a few examples that illustrate the close cooperation between the relevant authorities and, for instance, operators of hydropower stations:

a) Examples of sites where the federal government (Federal Ministry of Transport and Digital Infrastructure (BMVI) is involved through the German Federal Waterways and Shipping Administration (WSV) or the Federal Institute of Hydrology/ Federal Waterway Engineering and Research Institute:

(i) Wallstadt/Main pilot site: installation of an upstream migration facility on the basis of a contract between WSV and the hydropower station operator;

(ii) Offenbach/Main: construction of an upstream migration facility (WSV/State of Hesse) and downstream migration measures (Migromat through E.ON);

(iii) Eddersheim/Main pilot site: planning of upstream and downstream migration measures in a pilot project by the WSV (= here, also hydropower station operators).

Ireland

A programme has begun for the reintroduction of salmon to the Upper Lee System, i.e. to restore the natural run of salmon to the Upper River Lee, so that the river may achieve its salmon conservation limit over the long term. Collaboration between the Electricity Supply Board, Inland Fisheries Ireland and University College Cork.

Spain – Asturias

In areas where salmon are present, hydro-electric businesses collaborate with the administration responsible for fish resources by emptying the channels to check the fish and determine whether there are breeding adults present or signs of downstream migration (parr or smolt) and prevent them from entering the turbines.

Spain – Cantabria

There are no such initiatives.

Spain – Galicia

We have no knowledge of such cases. Fish passage mechanisms are proposed by the developer are examined (technically) by the body responsible for nature conservation, under the sectorial legislation on river fishery.

Sweden

River Ätran

The River Ätran is the most important salmon river on the Swedish west coast. In 1903 a power plant was established close to the mouth in the city of Falkenberg and later on another power plant was built in the same area. Salmon and sea trout had great difficulties passing the dam using the previous fish ladder. In 1946 the dam was equipped with a Denil fishway. Immediately salmon used the fishway and the salmon population in River Ätran is now of good status. Salmon parr densities have averaged 98 per 100m^2 since electrofishing monitoring started in 1959. According to data from an installed Vaci counter 3,000-5,000 Atlantic salmon and sea trout passed the power plant annually in 2000 - 2010.

Although the Denil fish way was functioning well for strong swimmers as salmon and sea trout, other species are hindered, among these red listed species as eel (*Anguilla anguilla*) and sea lamprey (*Petromyzon marinus*).

Also downstream passage of fish in the river has been a problem. Some attempts to decrease the mortality among downstream moving fish have been tested using trash gates and low-sloped fine-spaced racks. The targeted species are Atlantic salmon and anadromous brown trout. Smolt and kelt were radio-tagged and tracked in passing the facilities. An open trash gate proved to have a very low efficiency for smolt (7%) and most individuals passed through the racks and turbines. The efficiency was intermediate for kelt (40%) and several individuals died on the trash racks or remained upstream until the end of the study. The route seeking time was limited for smolts, but substantial for kelts. Using surface spill gates and fine-spaced racks the efficiency of leading smolts and kelts has been improved (Pers. comm. Ph. D. Olle Calles, University of Karlstad).

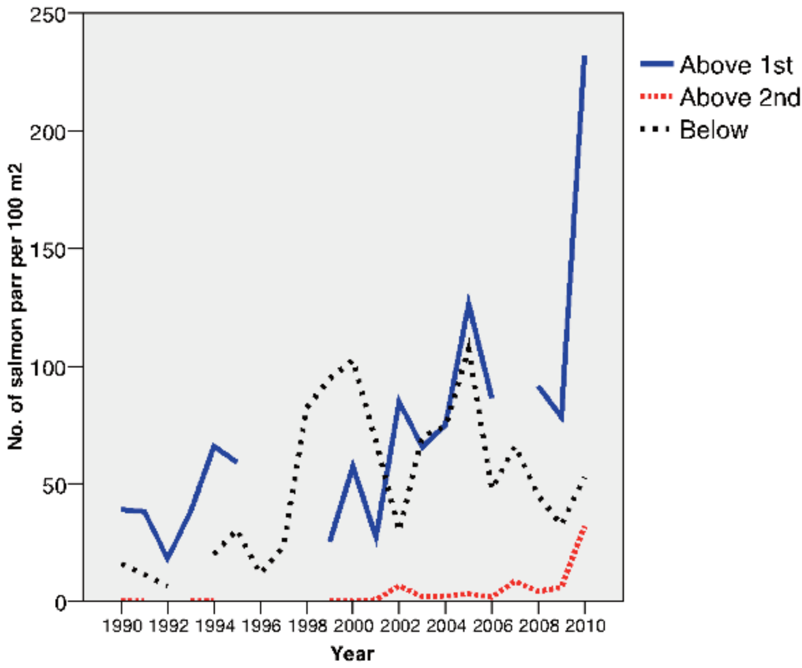
The city of Falkenberg took the initiative to start a process to remove the Herting dam on the River Ätran with support from county administrative board and national authorities. The Environment Court gave permission to remove Herting dam in 2012. In 2014 a part of the dam was removed, opening half of the main stem for free passage of fish and other species. The habitat in this part of the stem has been restored and a dam upstream guarantees a minimum flow of 11m^3/s. The older of the two hydropower stations will operate all year round but the newer power station, situated in the stem which has been opened for fish passage, will only operate during winter high flows.

River Himleån

River Himleån is small with an average annual flow of 2.6m^3/s. Today 38km of the river is passable for salmon after removal of three dams. In the 1980s the salmon in the river had been lost due to migration hindrances, acidification in the upper parts, eutrophication in the lower parts combined with canalisation for drainage of agricultural areas. In 1987 a few straying salmon from nearby River Viskan spawned near the mouth. The local fly fishing club in 1989 started with measures to improve habitat and fish passage. The first dam and small-scale hydropower plant in the main stem was removed in 1996. The second power plant and dam was removed in 1999. From 1989 to 2010, 60,000 tonnes of stones, boulders and gravel has been used to restore rapids and spawning areas. This was partly financed by governmental funds, but also by the voluntary work of the fly fishing club.

Salmon started to migrate upstream and successively the densities of parr have increased, whereas the general trend in Sweden is decreasing densities. It is estimated that available nursery areas for sea trout and salmon have increased from 3.6 to 8 hectares. Along with increased salmon and sea trout production the red listed eel has also increased in the system due to improved passage facilities. Upstream of the second dam the first eel was caught in 2001.

River Himleån salmon stock is today ranked as above conservation limits, i.e. from a lost salmon population to a healthy river in 23 years.



Average densities of salmon parr at electrofishing sites below the first dam, above the first dam and above the second dam. The dams were removed 1996 and 1999.

UK (England and Wales)

Through considerable effort by the Environment Agency, Natural England, the Department for Environment, Food and Rural Affairs (Defra), Rivers and Wildlife Trust, fisheries interests, landowners and community groups working together, between 2009-2014, more than £22million was invested in addressing 229 obstructions across England and Wales. This was, in many ways, made possible through Defra's River Improvement and Catchment Restoration Funding programmes.

Eight of the 63 fish passes and easements that have been built between 2009-2014 on England's 42 principal salmon rivers are known to have been linked to hydropower schemes. Two case studies are shown in paper CNL(15)14.

In Wales, there have been fish passage improvements at five major sites where a hydro scheme has been built using an existing structure and where that structure has previously been a barrier to, or impaired fish movement. These include sites on the Alwen, Elwy, Ogwen, Monnow and Taff. There have been a number of other sites on smaller streams where fish passage has been improved in association with a hydro development for example establishing easements on existing partial barriers such as weirs and culverts.

UK (Northern Ireland)

Pre-planning consultation is available for developers of hydro schemes and DCAL staff can advise applicants/developers of the requirements for fish passage standards they will have to meet. This means that all new schemes will meet the legislative requirements. There are also up to 10 old weirs used in hydro schemes where DCAL required a fish pass to be constructed thus improving fish passage at the site. Loughs Agency have a policy document on hydro schemes.

Fish passage has been improved at a number of sites in the past including;

R Blackwater, Benburb - Fisheries Conservancy Board, DCAL & local anglers

Sixmile water, Dunadry & Barbour's weir - Fisheries Conservancy Board, DCAL & local anglers

Lagan – DCAL, Rivers Agency

River Main, Randalstown – Fisheries Conservancy Board, local anglers

Finnis – Local angling club, DCAL, Rivers Agency, local landowner

Ballymoney River – Local council, DCAL & Rivers Agency

Lodge Burn - Local council, DCAL & Rivers Agency

Crumlin River - DCAL & local anglers under EU Grant scheme

Carey River - DCAL & local anglers under EU Grant scheme

Improving fish passage at a number of other sites is currently being considered along with a programme of stakeholder engagement to identify sites where fish passage could be improved with a view to trying to identify ways of carrying out the necessary works or removal of the obstacles.

UK (Scotland)

- Objectives for improving fish passage at existing hydropower developments are established in river basin management plans;
- The second river basin management plans are due to be published at the end of 2015 and will set objectives for improving fish passage for the second (2015 to 2021) and third (2021 to 2027) river basin planning cycles;
- In prioritising action to improve fish passage in the second river basin planning cycle, account is being taken of information provided by fisheries interests on the potential benefits to fish populations as well as information from hydropower operators;
- The 2011 Regulations enable SEPA to vary the authorisations for existing hydropower schemes so as to require the schemes' operators to introduce the mitigation necessary to achieve the plans' objectives for fish passage - subject to the costs of that mitigation being proportionate;
- To help secure improvements at barriers to fish passage caused by abandoned weirs and dams, a restoration fund has been established by Scottish Ministers. The fund is administered by SEPA;
- During the period of the 1st river basin management plan (2009 to 2015) fish passage has been improved at nearly 50 barriers, including a number of barriers caused by hydropower schemes.

Further details at:

http://www.sepa.org.uk/environment/water/river-basin-management-planning/second-cycle-development/;

http://www.sepa.org.uk/environment/water/water-environment-fund/.

Norway

The new R&D project SafePass (Safe and efficient two-way migration for salmonids and European eel past hydropower structures) is a result of active lobbying among stakeholders and R&D institutions. The Norwegian Research Council provides financial support.

Russian Federation

The fish ladder on the Pecha river (Tuloma river basin, Kola Peninsula) was built in 1962-1964 as a part of the Upper Tuloma dam construction. The fish ladder was ineffective for ascending Atlantic salmon and was completely rebuilt in 1992-1993 on the basis of scientific recommendations developed by A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences. Nowadays the Pecha fish ladder provides access to the spawning grounds in the Pecha river for Atlantic salmon.

United States of America

The most well-known example of collaboration between government and stakeholders is the Penobscot River Restoration Project. This project was described in in CNL(15)45 (Annex 2). However, this type of collaboration occurs at nearly every restoration site where dams are being removed or where fish passage devices are installed. Another interesting example of this type of collaboration is project SHARE (salmonhabitat.org) which has helped 10 landowners complete 154 habitat restoration projects since 2005.