	Council *Overview of adaptive management actions undertaken by Ireland to mitigate the negative impacts of climate change, with an assessment of the effectiveness of these actions, and lessons learned*	**CNL(23)54** **Agenda item: 7a)**

Overview of adaptive management actions undertaken by Ireland to mitigate the negative impacts of climate change, with an assessment of the effectiveness of these actions, and lessons learned

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Background

This paper accompanies the upcoming presentation to be given at the Theme-based Special Session (TBSS) at NASCO 2023, entitled 'Informing a Strategic Approach to Address the Impacts of Climate Change on Wild Atlantic Salmon'. It provides an Irish perspective on the impacts of climate change on Atlantic salmon (hereafter salmon) and on the development of management measures that can improve the resilience of salmon and their habitats to ongoing climate change.

Introduction

Prior to implementing climate mitigation measures, an assessment of the mechanisms through which changes in climate impact salmon and their habitat must be completed. Management actions must be customised not only to specific regions and jurisdictions but in some instances to individual river basins and coastal habitats occupied by salmon. Decision-making must incorporate localised climate information as well as the specifics of non-climatic human pressures that may compromise the resilience of individual salmon populations to climate change impacts. Not all salmon populations will face the same degree of climate exposure and in a pragmatic sense, not all proposed mitigation solutions can be successfully implemented in every circumstance. In this regard, the process of designing and implementing management actions that will prove successful is an intricate and evolving process. However such a thorough approach at this stage is warranted - mitigation strategies implemented now must continue to provide current conservation benefits under future climatic conditions, with climate change providing the backdrop against which the success or failure of management actions will be determined.

In Ireland most salmon-relevant adaptation work that has taken place to date has focused on firstly establishing an evidence-base that will inform effective mitigation strategies tailored to Irish salmon populations. The aim of this contribution is to provide a synopsis of current actions underway in Ireland related to climate change and Irish salmon. In response to each area, a brief summary of management actions are outlined, the rationale for their initiation discussed and some potential benefits and challenges to their implementation and success are reviewed.

How will climate change impact Ireland?

Action: Increase certainty in predicting the future climate conditions Irish salmon populations will experience

Ireland experiences a maritime climate dominated by the North Atlantic ocean-atmosphere system, resulting in cooler summers and milder winters than would normally be anticipated based on latitude alone. Owing to this complicated influence of North Atlantic variability, accurately forecasting the effects of climate change on Ireland is a difficult but critical step if effective climate mitigation solutions are to be tailored to Irish salmon populations. An

important step in this regard was the initiation of a four-year project in 2022 between Met Éireann (Ireland's state meteorological agency) and the Irish Centre for High-End Computing (ICHEC) based in the University of Galway. The project aims to improve model representations of the North Atlantic ocean-atmosphere system in global climate models under different emissions scenarios and use this improved accuracy to simulate Ireland's future climate. Crucially, this will include providing specific localised climate knowledge. The outputs will inform updates to salmon conservation strategies, as the more accurate model predictions will greatly decrease uncertainty surrounding the precise nature of future climate challenges facing Irish salmon populations. It is anticipated that this action will provide stakeholders, including fishery scientists and managers, with the most cutting-edge projections of Irish climate in the coming century to guide appropriate management strategies.

Evidence-based research programmes to inform mitigation strategies

Action: Establishing a national monitoring programme for delineating climatically vulnerable salmon habitat and for mitigation prioritisation

Inland Fisheries Ireland (IFI), the state agency tasked with the conservation, protection and management of wild salmonids, established a research programme in 2019 to ascertain the impacts of climate change on Irish fish stocks (Barry et al. 2022). In late 2020, a service-level agreement was entered between IFI and the Office of Public Works (OPW), the state agency responsible for the management of channelised rivers for land drainage purposes, to expand this research into reengineered rivers with altered hydrology and ecological functioning (Kelly et al. 2022).

To date these programmes have enabled IFI to develop a nationwide environmental monitoring network in 12 salmon catchments. There are currently *c.* 380 environmental sensors collecting data in salmon river habitat across Ireland, measuring a range of salmon-relevant metrics including water temperature, water levels, dissolved oxygen and meteorological data. IFI's National Climate Mitigation Research Programme is using the recorded data and subsequent analytical techniques to develop maps identifying salmon river basins and habitat locations most at-risk from climate change impacts. Resulting habitat 'risk-maps' have already been developed for several important salmon catchments. By delineating cold-water refugia and vulnerable river reaches experiencing excessively warm temperatures in an easily visualised manner, the programme has received positive reactions from fishery and catchment managers and will greatly assist with resourcefully targeting mitigation measures in future.

Two state-of-the-art lake monitoring platforms in regionally important salmonid lakes have been installed which can transmit water quality and temperature data in real-time to inform management practices. In 2023, a further 2 monitoring stations with live data transmission will be installed in rivers. These sensors inform fishery managers of harmful climate and environmental conditions for salmon as they occur in real-time, and can prove effective as accurate, evidence-based 'climate warning' systems. These warnings can initiate reactive management measures such as the initiation of protective angling restrictions whenever water temperatures exceed harmful conditions for salmon.

Action: Development of the National Salmonid Index Catchment (River Erriff) as a centre for salmon-climate research excellence

A dedicated IFI field research facility located in the River Erriff, designated as the National Salmonid Index Catchment (NSIC), has maintained a complete census of the migration of juvenile and adult salmon populations, along with other pertinent salmon biology records, for the past four decades (Millane et al. 2023). Recent management actions have included further investment in the research infrastructure including upgrades to trapping and lab facilities and

in 2019 a catchment-wide environmental sensor network was installed to monitor environmental parameters in the catchment and to track the impacts of climate change. Salmon tagging programmes (including the NASCO-coordinated EU-funded SMOLTRACK project) have been initiated to improve understanding of climate and temperature impacts on marine and freshwater survival. A primary aim of the NSIC is to improve public and stakeholder perception and awareness surrounding the strong influence of climate on salmon ecology. The effectiveness of this implementation will continue to strengthen with the extension and further analyses of these invaluable long-term ecological datasets.

Identifying and remediating anthropogenic stressors that compromise salmon resilience to climate change

In Ireland, poor water quality and modified hydromorphology are ostensibly the most important pressures that compound negative climate impacts on salmon. The primary issue underlying both of these pressures relates to the large-scale modification of land, usually for intensive agricultural practices (e.g. grazing pastures) with urbanization and forestry also playing a role. In terms of water quality, excessive loading of phosphates and nitrates increase plant and algal biomass in Irish coastal and freshwaters, which can decrease water oxygen content. In combination with warm, dry weather spells during summer that will occur as a consequence of climate change, the risk of low oxygen, warm water conditions is heightened in waters with poorer water quality.

Debilitated hydromorphology is another large concern with some 28.5% of the total watershed area in Ireland currently managed by the OPW for land drainage purposes (primarily to prevent flooding of agricultural land). This simplification of the complex riverscape through reengineering typically removes riparian vegetation and pool habitat, which in combination often provide salmon populations a refuge to recover from heatwave events. In addition, river barriers can compromise the thermal integrity of salmon river habitat, increase stress in fish attempting to pass barriers during warm summer spells and prevent fish from migrating to colder stream habitat.

Action: Regulations to protect waterbodies from nutrient pollution arising from agricultural sources

The Irish government published the fifth iteration of the *Nitrates Action Programme* in 2022[1]. The programme was informed by the Environmental Protection Agency's (EPA) findings that only just over half of the surface water bodies in Ireland have satisfactory water quality status. Notable new measures include an improved compliance and enforcement programme, with inspections to increase by 5-10%. Additional measures will include new excretion rate bands for livestock as means to monitor numbers of allowable livestock per unit area and limits to chemical fertiliser appliance. The anticipated outcome of these actions will rely entirely on how strictly the compliance programme is enforced. Despite the EPA urgently stressing the need to address poor water quality issues, trends in water quality remain a concern with a 39% increase in nitrates and 17% increase in phosphorus loading based on data from the most recent monitoring period (2019-2021) published.

Action: Applied research programmes to assess hydromorphological recovery strategies aimed at improving salmon habitat resilience to climate change

Inland Fisheries Ireland and the OPW have renewed a shared service agreement - *Environmental Research & Monitoring Programme* (Fleming et al. 2022), which is now in its fourth cycle (2023-2027). A primary objective of the research programme is to develop an

[1] https://www.gov.ie/en/publication/f1d01-fifth-nitrates-action-programme-2022-2025/

understanding of how river remediation works and modification of current river engineering practices may alleviate the compounding effects of climate change and channelisation. This programme complements IFI's core hydromorphology research, which assesses similar issues in more near-natural salmon rivers, as well as the CatchmentCARE[2] programme, a cross-border, multi-agency EU INTERREG funded initiative which aims to improve the resilience of debilitated, agriculturally-intensive river systems. These programmes are achieved primarily through targeted applied research. The anticipated result for stakeholders is that a protocol will be developed containing direct measures and recommendations proven through research to improve climate resilience of salmon rivers. It is envisaged that such protocols will form the basis of a more ecologically-sustainable way to manage channelised rivers in future.

In addition, IFI has established the *National Barriers Programme*[3], aimed at reducing the impact of barriers on fish migration. This action has thus far created a barriers assessment tool and a national database of river barrier locations. Guidance documents are also in preparation that will inform on appropriate practices for barrier-mitigation techniques. The anticipated effectiveness of the programme is an amelioration of the additional stress barriers can impose upon salmon populations, particularly during warm, dry weather spells associated with climate change.

Conclusion

In Ireland, most management actions aimed as mitigating climate impacts on salmon have so far focused on implementing applied, evidence-based research programmes to inform best practices (e.g. Inland Fisheries Ireland (2020)) . Many of these research programmes are well underway and have already begun to inform effective mitigation strategies (e.g. identifying and prioritising habitat restoration in climatically vulnerable sites, conserving climate resilient sites, informing angling practices and fishery management, raising public and governmental awareness). The continuation and evolution of these programmes are essential to continue to provide updated, cutting-edge scientific information for salmon conservation purposes. Additional longer-term environmental monitoring (e.g. of water temperature, water quality and salmon population dynamics) also provide critical baselines which can continue to raise awareness on the negative implications of climate change in combination with other aggravating pressures for salmon. The role of policy makers, resource managers and stakeholders in taking this advice onboard and implementing it through new regulations and incorporating it into environmental management legislation is now urgent, given the impending threat that climate change poses to Irish salmon populations.

Acknowledgments

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[2] https://www.fisheriesireland.ie/what-we-do/research/catchmentcare
[3] https://www.fisheriesireland.ie/what-we-do/research/national-barriers-programme

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