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THE PENTLAND SALMON INITIATIVE: A NEW RESEARCH PARTNERSHIP EXPLORING THE POTENTIAL INTERACTIONS BETWEEN MIGRATORY FISH AND MARINE RENEWABLES

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ABSTRACT

Atlantic salmon (*Salmo salar*) are iconic and economically important fish, but their migratory behaviour during passage through Scottish coastal seas is not well understood, and there are several key questions which need to be answered in order to predict possible interactions with marine renewable energy arrays. Do migrating salmon (adults and post-smolts) travel through marine renewable energy development areas? Will migrating fish actually encounter arrays of devices as they pass through these areas? What effects might these encounters have on migrating salmon, and what might be the consequences of these interactions for fish populations?

In response to these questions, the Environmental Research Institute has established the Pentland Salmon Initiative - a new partnership which aims to engage a growing number of organisations with interests or experience relevant to marine renewables and salmon migration, with a particular focus on the Pentland Firth. This site represents not only a potential bottleneck for migrating salmon but also a key site for the developing marine energy sector. We are actively seeking to build and extend collaborative programmes under four broad themes, which are outlined below.

Why the Pentland Salmon Initiative?

Wild Atlantic salmon have a fascinating life-cycle. After hatching they spend up to three years in freshwater, before undertaking long distance marine migrations across the North Atlantic. Following a period of time feeding at sea (which typically lasts from one to three years), these fish navigate back to the very rivers in which they themselves hatched in order to spawn. The marine migrations of this species, particularly their journeys across the sea and around Scotland's coasts and the cues used to guide these migrations, remain poorly understood. This is all the more significant because numbers of fish successfully returning to rivers to spawn has been in decline for decades.[1] *Salmo salar* is listed in Annex II of the EU Habitats Directive, and 11 Scottish rivers are designated as Special Areas of Conservation (SACs) for *S. salar* (the species is a 'qualifying feature' in a further 6 rivers). Atlantic salmon also support significant economic activity in Scotland,[2] including in rural and remote communities.

Particularly in the case of adult salmon returning to rivers of the Scottish East coast (and also potentially salmon post-smolts heading out to sea from some river systems), the migrations of Atlantic salmon may include passage through the Pentland Firth,[3] the narrow stretch of water connecting the North Sea to the wider north Atlantic. Many high value salmon rivers, including the Thurso, Naver and Halladale, enter the sea in the vicinity of the Firth, which is an extremely energetic tidal channel.[4] This stretch of water (and the water surrounding the Orkney Islands) is the focus of some of the world's most substantial proposed developments of wave and tidal energy.

This possible overlap between the renewable energy industry and the migrations of salmon has been the impetus behind the formation of the Pentland Salmon Initiative, which aims to foster a partnership of stakeholders - including academics, fishery boards, planners and developers – with interests in marine renewables and salmon in the special context of the new developments along the Caithness and Sutherland coasts. The ultimate goal of the partnership will be to move towards addressing the knowledge gaps concerning the possibility of interactions between migrating fish and renewable energy developments. Our main activities fall under four broad themes, and this paper showcases some of the included activities.

THEME 1: MODELLING SALMON MIGRATION IN SCOTTISH SEAS

In order to understand whether salmon might interact with marine renewables, we need to know more about where they go during their marine migrations; modelling approaches are integral to this effort. One approach is the use of particle tracking models (PTMs); these allow trajectories of individual animals to be simulated within oceanographic models (Fig. 1), and could be used to predict passage rates of salmon through renewable energy sites. Supported by The Crown Estate, ERI has undertaken a wide ranging review of PTM methods, and has built such a model for the Pentland Firth as a demonstration exercise[5]. Guidelines have also been produced to facilitate further development of this approach. The partnership also continues to explore other innovative techniques for modelling movements of migratory fish around Scotland.

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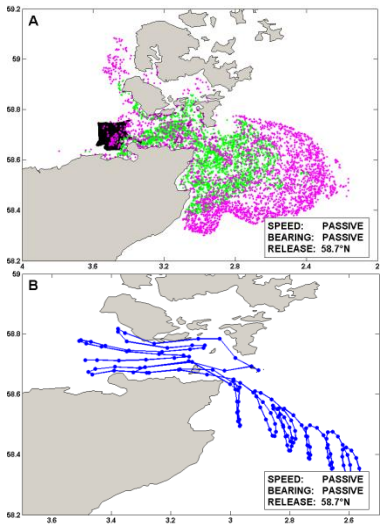

Figure 1. Outputs of a particle-tracking model (PTM) demonstration for the Pentland Firth. A: Positions of passive particles released in a hydrodynamic model after 72 hours (green) and 143 hours (pink). B: example trajectory of a single passive particle from the same simulation.

THEME 2: COLLECTING SALMON MIGRATION DATA

Few data are available on salmon behaviour during their coastal migration. To close this 'knowledge gap' and gain insights into coastal salmon migration, the partnership will work with developers and technology firms to combine state-of-the-art tracking and telemetry technology with more tried and tested approaches. Working with Marine Scotland Science, ERI has also collated, digitised and geo-referenced data from a range of tagging studies – this data is currently informing a modelling study using a simple agent-based model to explore the coastal movements of fish around Scotland.

THEME 3: EXPLORING EFFECTS ON MIGRATING SALMON

Migrating salmon may be affected by noise from construction and operation of renewable energy devices. We aim to investigate the behavioural responses of wild salmon to man-made sounds under natural conditions, in parallel with detailed characterization of sound fields using a variety of different sound measurement metrics. Our aim will be to determine whether sound causes significant changes in behaviour or interferes with fish navigation.

It is critical for regulators to gain better knowledge of the levels of noise that may affect the behaviour of salmon adversely. We have gathered together expertise on salmon behaviour, the salmon auditory system, the propagation of underwater sound, and the measurement and description of sounds. We have plans for a series of experiments aimed at elucidating the effects of underwater sounds upon the behaviour of salmon in the wild.

Noise from man-made sources pervades the marine environment. It may come from shipping, seismic surveys, pile driving and construction activities, sonar, and the operation of renewable energy devices. Negative impacts have been demonstrated on a wide range of marine animals although population consequences have been more difficult to assess.

The auditory system is a critical source of environmental information for most animals, including fishes. By listening to the sounds from sources around them, fish can potentially learning a great deal about the environment and events within it. Sound travels well through water and is capable of conveying significant information over considerable distances. Sounds may play a role in: navigation, foraging for prey, detection of predators and communication of reproductive state, and there is evidence that some fishes may use sound for habitat selection.

The sounds that are important to fish, including salmon, go beyond those that are detected by man. There is strong evidence that salmon and cod detect and respond to infrasonic frequencies (below 20Hz) as well as sounds at the lower end of the audio spectrum. In addition, fish are sensitive to particle motion rather than sound pressure – only a few species can detect sound pressure. It has been suggested that natural sources of low frequency sound including seismic waves may serve as cues in the orientation and navigation of salmon.

The Pentland Salmon Initiative will set out to measure the amplitudes, frequencies and direction of low frequency acoustic and seismic waves on the seabed and in coastal waters to determine their possible utilization by salmon and other organisms for location, orientation and navigation. The potential for man-made sounds to interfere with or mask these natural sounds will be assessed. In particular, experiments are planned where natural and man-made sounds of differing characteristics will be presented to salmon, and the effects observed.

Captive fish show only limited behavioural repertoires, and they are de-sensitised to sound exposure as a result of living in noisy environments. Experiments on wild fish have much greater ecological validity. Experiments on salmon in the open sea, estuaries and sea pools, where the behaviour of wild salmon can be properly observed and assessed, are challenging, but recent experiments where coastal species of fish have been tracked by means of ultrasonic tags, and by sonar systems, have shown great promise. Sites are being investigated where such techniques can be applied to wild free-swimming salmon, and their responses to sound exposure observed.

THEME 4: MONITORING SALMON POPULATIONS IN NORTHERN RIVERS

To facilitate long-term monitoring, an electric-fishing survey of all Caithness rivers was completed in September 2013 by the Caithness District Salmon Fishery Board in collaboration with The Crown Estate, ERI and The North Highland College. Juvenile salmon were examined at 22 sites distributed throughout the six major rivers in Caithness using depletion electric-fishing methods. Density and biomass values demonstrated that salmon fry (hatched 2012) and parr (hatched 2011) were at high abundance throughout the Caithness rivers. Indeed, at some sites high densities were associated with impaired growth rates of individuals, indicating that the sites were fully saturated. As intended, these survey data represent a definitive account of the status of juvenile salmon in the Caithness rivers in the phase preceding the marine developments projected for the northern Scottish coasts. The completed analyses will form a rigorous basis for future comparisons. Since the methods are now tested and proven, the survey can be repeated in future years and its geographical range can be extended with confidence. More generally, a variety of additional monitoring measures, including the analysis of catch data and the use of fish counters, are being evaluated by Pentland Salmon Initiative partners, with the intention that these could be rolled-out on a wider scale, in collaboration with stakeholder groups.

Figure 2. Electric-fishing in the Wick river

CONCLUSIONS

There are many unanswered questions regarding salmon migration through Scottish seas. The formation of the Pentland Salmon Initiative is only the first step in attempting to draw together a network of stakeholders to work towards addressing some of these issues and building a lasting partnership to continue this work into the future. It is to be hoped that through increased understanding of the migrations of salmon, and of their potential interactions with a range of developments, we can safeguard the future of salmon in the north of Scotland.

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REFERENCES

[1] G. Chaput, "Overview of the status of Atlantic salmon (*Salmo salar*) in the North Atlantic and trends in marine mortality," *ICES J. Mar. Sci.*, vol. 69, no. 9, pp. 1538–1548, Apr. 2012.

[2] A. Radford, G. Riddington, J. Anderson, and H. Gibson, *The Economic Impact of Game and Coarse Angling in Scotland*. Edinburgh: Scottish Executive, 2004, p. 70.

[3] I. A. Malcolm, J. Godfrey, and A. F. Youngson, "Review of migratory routes and behaviour of Atlantic salmon, Sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewables.," *Scottish Mar. Freshw. Sci.*, vol. Volume 1, p. No 14. 82pp, 2010.

[4] M. C. Easton, D. K. Woolf, and P. A. Bowyer, "The dynamics of an energetic tidal channel, the Pentland Firth, Scotland," *Cont. Shelf Res.*, vol. 48, pp. 50–60, Oct. 2012.

[5] A. J. Guerin, A. C. Jackson, P. A. Bowyer, and A. F. Youngson, *Hydrodynamic models to understand salmon migration in Scotland*. The Crown Estate, 2014, p. 116.