CREW CENTRE OF EXPERTISE FOR WATERS

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Research Summary

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The impact of shadow flicker or pulsating shadow effect, caused by wind turbine blades, on Atlantic salmon (*Salmo salar*)

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BACKGROUND

Onshore wind farm developments have become a common sight within the Scottish landscape, and the installed capacity of onshore wind-generated electricity has expanded, to meet climate adaptation needs. Impacts from the construction and installation of wind turbines next to rivers may include changes to water quality or damage to vulnerable freshwater habitats. The impact of shadow flicker, a flickering or pulsating light to shadow cast effect, caused by the motion of the wind turbine blades as they pass in front of the sun, on freshwater fish is unknown.

Atlantic salmon (*Salmo salar*) are an important and protected species of fish that are undergoing a significant decline across their natural range. They are a qualifying feature within 17 Special Areas of Conservation (SACs) in Scotland. The extent to which Atlantic salmon may be exposed to, and potentially impacted by, shadow flicker is not well understood. The aim of this project was to establish, from a review of existing studies, whether Atlantic salmon, individually or as populations, could potentially be affected by shadow flicker from onshore wind turbines.

RESEARCH UNDERTAKEN

Our current understanding of the possible effects of shadow flicker on Atlantic salmon was investigated by reviewing the available literature for existing studies of a similar or relevant nature. Various databases and web-based search engines were used to identify these studies, relevant information was extracted and summarised, and potential impacts across the salmon's lifecycle identified. Where appropriate, potential mitigation methods were identified that could reduce any impacts on Atlantic salmon.

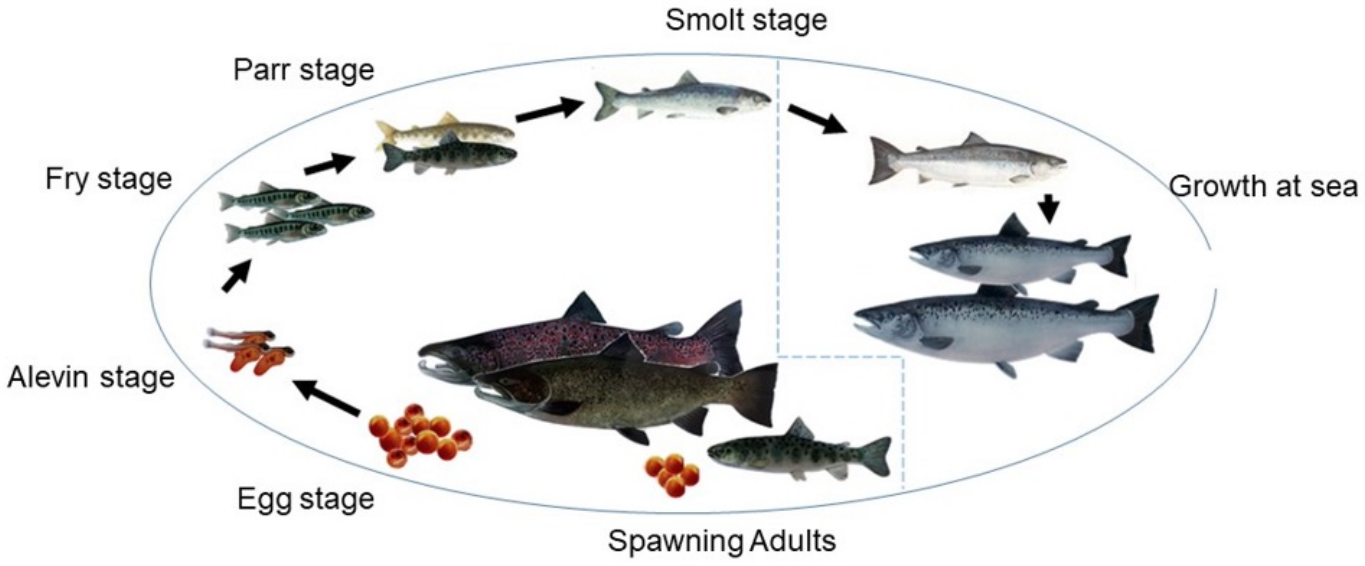

Figure 1 Life cycle of Atlantic salmon (*Salmo salar*). Note that six life stages to the left side of the dotted blue line occur in freshwater, and are the focus of this project's scope, whilst the right side of the dotted blue line involve life stages at sea. Colin Bean, 2021.

KEY FINDINGS

There was no direct evidence available, either from laboratory experiments or studies of wild fish, that describe the effects of shadow flicker on Atlantic salmon or any other fish species. Based on the available literature, and our expert opinion, there is currently insufficient evidence to support or refute any biological or ecological impact of shadow flicker on Atlantic salmon. We make the following key findings:

It was the authors' opinion[1] that, at an individual level:

- It is highly unlikely that the **egg stage**, the **alevin stage** or the **adult stage** of Atlantic salmon would be impacted by shadow flicker under any local habitat conditions.
- In their preferred riffle habitats of a stream, it is unlikely that the **fry stage** of Atlantic salmon would be impacted by shadow flicker. While fry of salmon are typically found in riffle habitats, fry found elsewhere in streams may be exposed to more shadow flicker than those found in riffles.
- The evidence available to establish whether shadow flicker would impact the **parr life-stage** of Atlantic salmon is inconclusive.
- Shadow flicker is unlikely to impact the **smolt life stage** of Atlantic salmon. Although most salmon smolts migrate during darkness, some smolts do move in daylight hours towards the end of the smolt migration period. The impacts of this potential daylight exposure to shadow flicker are currently unknown but are likely to be low due to the limited time any smolt would be exposed to this phenomenon.
- It is likely that Atlantic salmon will become habituated to the visual motion of wind turbine blades. However, it is unclear from existing studies whether this learned knowledge could be used by fish in a new or novel situation. For example, whether an individual would respond differently to an aerial predator with a movement pattern similar to wind turbine blade motion.

It was the authors' opinion[1] that, at a population level:

- It would be possible to extrapolate any impacts on individuals at different life stages to the population level using existing stock-recruitment models. However, the number of parr (or other stages) lost from a system as a direct result of shadow flicker, and no other factor, would have to be quantified.

Mitigation can only be drawn up when a significant impact is evident. Should this be found, then there are four possible measures available to mitigate the impact of shadow flicker cast from wind turbine blades on the water surface and fish populations:

- For **existing** wind farms:
  a. Changes to the operation of existing wind turbines.
  b. The use of riparian screening to prevent shadow flicker reaching the water surface.
- For **proposed** wind farm developments:
  c. Locating new wind turbines at far enough distances to prevent shadow flicker casting on the water surface.
  d. Use appropriately sized wind turbine stem, such that wind turbine blades are not able to cast shadow flicker on the water surface.

KEY CONCLUSIONS:

The following conclusions are based on the authors' opinion[1] following the review of the available literature:

- There is no specific evidence available to support or refute any biological or ecological impact of shadow flicker from wind turbine blades on Atlantic salmon.
- The parr life stage of Atlantic salmon was identified as being most likely to be exposed to shadow flicker, but there is no evidence to suggest this would impact the biology or the ecology of the individual.
- There is no evidence available to support whether any habituation to the visual motion of wind turbine blades would impact on the response of an Atlantic salmon to potential predators.
- If an impact was identified, this would need to be interpreted in terms of the number of fish lost as a result of the effects of shadow flicker in comparison to any of the multiple stressors currently facing Atlantic salmon in our rivers.
- Should an impact be identified, various forms of mitigation were identified to prevent shadow flicker being cast on river surfaces.

1 Authors' opinion has been formed based on a review of the literature and previous experience gained through a foundation of research in the freshwater environment. The opinions expressed have been formed with low confidence due to the level of extrapolation required resulting from to the lack of information and evidence available.

RECOMMENDATIONS

Advice for further research and recommendations have been provided in the main report. However, the review of available literature (peer-reviewed and grey from national and international sources) has highlighted a lack of basic understanding of the role light patterns may play for Atlantic salmon in rivers.

GLOSSARY

Term	Definition
Adult	The stage at which an individual salmon can produce offspring.
Alevin	Newly hatched salmon up to a few months of age.
Fry	Young salmon from a few months after hatching to approximately one year of age.
Migrate/Migration	The process of movement from one area to another for the purposes of growth and/or reproduction.
Parr	Young salmon from approximately one year of age until they begin moving down to sea.
Smolt	Young salmon moving downstream and preparing for life at sea, typically aged two to four years old.

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