

	Council <i>Update on the Review of the Effect of Salmon Aquaculture on Wild Atlantic Salmon Populations – May 2024</i>	CNL(24)12 Agenda item: 4h)
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Update on the Review of the Effect of Salmon Aquaculture on Wild Atlantic Salmon Populations – May 2024

Purpose

The purpose of this paper is to provide Council with an update on the efforts to provide the latest scientific knowledge on the impacts of sea lice and escaped farmed salmon on wild salmon.

Decisions

- no decision is required.

Background

At its 2021 Annual Meeting, [CNL\(21\)62](#), NASCO agreed to fund a study to provide the latest scientific knowledge on the impacts of sea lice and escaped farmed salmon on wild salmon. A detailed proposal to enable this work to be conducted was provided to Council in 2022, [CNL\(22\)07](#).

The proposal laid out the approach to be taken to provide a State of Knowledge paper where the goal is to conduct a systematic review and potential meta-analysis of the effect of (1) salmon lice and (2) escaped farmed salmon on wild Atlantic salmon. The estimated costings for the work were €83,000. The work of the Expert Group would be co-ordinated by Paddy Gargan with the following members:

Ian Bradbury (escaped farmed fish); Damien Brady, (coastal ecology); Simon Jones (salmon lice); Sten Karlsson (escaped farmed fish); Eva Thorstad (salmon lice); and Knut Wiik Vollset (salmon lice).

The Group agreed that it was necessary to structure this process in a transparent and rigorous way to ensure that the findings are robust and control for bias. To structure the process and achieve this end, the Group contacted Steven Cooke, Director of the Canadian Centre for Evidence-Based Conservation, in May 2022 and invited him to join the Group. Professor Cooke with his team will guide the process of critical appraisal. Professor Cooke has led over 30 evidence syntheses over the last five years and is familiar with relevant methods.

At the 2022 NASCO Annual Meeting, [CNL\(22\)53rev](#), Council asked the Secretary to liaise with the co-ordinator of the Expert Group to request:

- a) the feasibility of including the impact of disease pathogens from farmed fish in their analysis;
- b) the provision of any resulting additional costs;
- c) the provision of a timetable to illustrate how the funding from NASCO could be provided over two financial years; and
- d) that a representative of the Group present an update to Council at the 2023 Annual Meeting; and
- e) to consider the responses from the Expert Group to the requests inter-sessionally.

In response to items a) and b), after discussion with the Group, the co-ordinator contacted Åse Helen Garseth from the Norwegian Veterinary Institute and she agreed to join the Group and

lead the disease pathogen work, if Council agreed to the addition of that work. Dr Garseth provided an estimated cost of €45,000 to include the additional cost on disease pathogens.

In late January 2023, the Council discussed, inter-sessionally, the possibility of including the disease pathogen work into the State of Knowledge paper. The Parties decided that, as NASCO has not adopted a policy on disease pathogens, together with the additional costs involved, not to include the disease pathogen aspect in the State of Knowledge paper. With regard to item c), a timetable is provided below to illustrate how funding will be provided over two financial years. This report update addresses item d) above.

The Agreed Approach

After considerable discussion during the early part of 2022, the Expert Group agreed that the approach that should be taken for the genetic introgression work and the sea lice work was quite different. Two sub-groups have, therefore, been formed. For the genetic introgression aspect, this subject was reviewed in 2017 and the relevant experts in the Group felt they have all the relevant literature and therefore a systematic review and critical appraisal was not necessary. There is also a lot more definitive information on the impacts of escaped farmed salmon on wild salmon and little or no conflict in the literature on the impact of escapes.

For the sea lice work, the Group felt that a systematic review and critical appraisal of the literature will be required and the approach and methodology that will be taken will be different to the escapes work. It was, therefore, agreed that one paper on the genetic introgression work and a separate paper on the impacts of sea lice would be produced. The possibility of combining the findings of both papers into a third policy paper with management implications has also been raised.

Proposed Working Methods for the Genetic Introgression Work Programme

The escape of farmed salmon has been documented everywhere salmon farming occurs and escapees have repeatedly been shown to interbreed with wild salmon, resulting in genetic changes to wild populations (Karlsson *et al.* 2016, Glover *et al.* 2017). The resulting offspring of escaped farmed salmon display reduced survival in comparison to wild salmon (Fleming *et al.* 1996, Fleming *et al.* 2000, McGinnity *et al.* 2003, Sylvester *et al.* 2019, Wacker *et al.* 2021) and resulting population decline has been demonstrated both experimentally and through simulation studies (Bradbury *et al.* 2020, Castellani *et al.* 2015, 2018; Fleming *et al.* 2000, McGinnity *et al.* 2003, Skaala *et al.* 2019). In contrast to the effect of salmon lice, the effect of genetic introgression is a much broader research question as the impacts may affect various life history stages differently (Bolstad *et al.* 2017, 2021). Consequently, although there are numerous studies on the effect of genetic introgression on wild fish, it may be a more difficult topic on which to conduct a meta-analysis. Given this, the introgression paper will review the large body of work evaluating the impact of escaped farmed salmon on wild salmon populations, focusing on the presence of escapees in the wild, evidence for hybridisation and introgression and the consequences for wild populations and, where possible, focusing on the mechanisms and magnitude of effect.

The working methods will review the effects of genetic introgression from the information below:

- data on number or presence of escapees in wild rivers;
- genetic estimates of introgression in the wild;
- modelling the population impacts of escapees and introgression;
- estimates of hybrid survival and reproductive success;

- experimental and modelling evidence of population response to hybridisation;
- changes in life history traits of wild salmon populations exposed to escapees;
- changes in other traits including immune response, lipid storage, gene expression, or behaviour (including increased predation risk) due to hybridisation;
- the combined effect of introgression and supplementary stocking; and
- the geographic extent of impact in terms of how far escaped farmed salmon spread.

Proposed Working Methods for the Sea Lice Work Programme

The literature search for sea lice will be conducted in collaboration with the Norwegian Institute for Nature Research (NINA), the University of Bergen and the Institute of Marine Research in Norway. During this process, exclusion criteria will be defined through discussion with the defined experts for the different topics. The process of the literature search will involve reading a subset of the papers found in initial searches and defining exclusion terms that can identify non-relevant literature. The literature search began in January 2023 and continued until March 2023. Consistency checks were undertaken in April. After full-text screening and feedback from the sea lice sub-group, data extraction and critical appraisal was conducted in September / October 2023.

Once the literature search is completed, a standardised critical appraisal of all the literature will be conducted. Critical appraisal is an important step for identifying and evaluating sources of bias. Some studies report conclusions that are poorly supported by their data. Critical appraisal involves developing a method of scoring individual studies where those studies with rigorous experimental design (e.g. representative sampling, large sample size, replication in space and time, relevant comparators etc.) would score well and ones with weak experimental design would be scored poorly. After scoring it is possible to conduct analyses that only use high-quality studies, to conduct analyses on high-, medium- and low-quality studies and compare findings (i.e. by means of sensitivity analyses with meta-analysis) or downweight the influence of low-quality studies in formal analysis. All decisions regarding critical appraisal are recorded so that readers can understand the basis for rankings. For these reasons, it is important that the critical appraisal tool be developed with care. Using a workshop that involves both subject matter experts and evidence synthesis experts is critical for generating a tool that reflects research standards across disciplines. The critical appraisal was finalised at a three-day meeting in Edinburgh in February 2023.

Based on the critical appraisal, an evaluation will be made as to whether there is sufficient empirical data and relationships developed to undertake a meta-analysis e.g. randomised control studies. If so, resources will be allocated for data extraction for search and analysis.

Genetic Introgression

Progress since the Workshop in February 2023

The genetic introgression sub-group held a number of meetings and invited more scientists into the sub-group in order to have a broad geographical coverage. The sub-group now comprises the following experts;

- Scandinavia: Sten Karlsson; Eva Thorstad; Geir Bolstad;
- British Isles: John Gilbey; Phil McGinnity;
- North America: Ian Bradbury; Brendan Wringe; and
- Iceland: Leó Gudmundsson.

The full sub-group developed an outline for the paper and identified tasks to be followed up. The most important task was to collect existing data for the different regions in the distribution range on aquaculture and estimates of genetic introgression. The goal is to create a map of aquaculture and the level of genetic introgression in wild salmon stocks in the whole distribution range of Atlantic salmon.

Genetic Introgression Project – Progress in 2024

For the genetic introgression work, the individual member institutions have gathered data to be included in the manuscript. Specifically, the group aim to create a short and concise manuscript of the status of farmed salmon and its genetic impact on wild salmon, where the main product will be a map showing the scale of farmed salmon production in the North Atlantic and correspondingly data on farmed to wild genetic introgression. The team had a meeting in April where they decided how to pull all the data together and create a data table with farmed salmon production and genetic introgression data. This work is progressing well and a map is being prepared.

The proposed paper will be a straight to the point paper with a synthesis of the knowledge: the magnitude of genetic introgression and the consequences for wild salmon populations. The group believe the paper may be suitable for the journal NATURE communications. What will make this paper different from what has been already published is that the data on farmed salmon production and genetic introgression will be presented throughout the distribution range of Atlantic salmon.

Sea lice Systematic Review

Progress since the Workshop in February 2023

Following the workshop in February, search strings vetted at the workshop were rechecked with a librarian at University of Bergen as well as librarians at NINA. No changes were made. A title and abstract screening questionnaire was developed and tested. Searches have been performed in three bibliographic databases (i.e. Web of Science, Scopus and Proquest), resulting in 1845 unique hits after duplicate removal. Before screening began, two reviewers, using a subset of 10% of these search results, undertook a consistency check to ensure consistent and repeatable decisions were being made. The results of the consistency checks were compared between reviewers and any discrepancies were discussed. All 1845 items have been screened at title and abstract. A call for grey literature was developed and is in circulation. Detailed accounting of all reviewer activities has been kept and will be used in the development of the review protocol.

The sea lice sub-group invited the following sea lice experts to participate in the sub-group: Sussie Dalvin – Institute of Marine Research, Norway; Sandy Murray – Marine Scotland Science; Frank Nilsen – University of Bergen Norway; and Sam Shephard – Inland Fisheries Ireland.

Sea Lice Impact Project – Progress in 2024

The systematic review analysis is progressing well and a summary of work undertaken is set out below. A systematic review protocol was developed entitled ‘Impacts of sea lice from aquaculture on wild Atlantic salmon: – Does exposure to sea lice from aquaculture have a population-reducing effect on wild Atlantic salmon?’. The protocol achieved the following results:

Literature Searches:

A total of 2784 papers/documents were screened with 1931 relevant using the programmes WOS / Scopus / ProQuest. An additional 293 papers / documents were drawn from the grey literature and 100 from Google Scholar and another 460 from Google Scholar alternative search strings.

This process Identified 17 papers with primary data: Field studies identified for extraction (Random Control Trials study design):

- 10 papers containing primary data identified for extraction;
- all 10 papers have been critically appraised (based on the current state of the tool);
- all 10 papers have had quantitative data extracted;
 - 113 data entities.

Observational studies:

- 4 Control-impact (CI): multisite with/without aquaculture;
- 1 Before-after (BA);
- 2 time series (with baseline) studies;
- all 7 papers have been critically appraised (based on the current state of the tool).

Four meetings were held in March to discuss analysis considerations. Given the evidence base, the focus for the meta-analysis will be on the Randomised Control Trial (RCT) studies (10 papers, 113 datasets). Using evidence from multiple North Atlantic countries, this rigorous systematic review will include a quantitative synthesis using robust meta-analytical methods to provide estimates of the overall population-level effect of sea lice from aquaculture on wild Atlantic salmon. Due to differences in study design and reported measurements of sea lice impact between experimental and observational studies, separate meta-analyses will be performed to obtain summary estimates of the sea lice impact. It would be inappropriate and open the door to criticism to attempt to combine studies using both designs in a single analysis. In doing separate meta-analyses, this will ensure that all available evidence is used while following appropriate statistical methodologies. These estimates will be compared narratively and discussed in the report, including limitations of each study design as related to the critical appraisal findings.

The meta-analysis is proceeding on the RCT studies. As noted above, the quantitative data has been extracted from all the studies and unique data sets have been identified (i.e. sometimes the same data has been used in more than one document). A few of the studies provide information / estimates on the sea lice infestation pressure along the out-migration route. The project team is currently in the process of developing a methodology to incorporate infestation pressure (INF P) into the analysis. Finally, the team has begun to outline the final report by drafting the introduction, materials & methods etc.

Overall Costing

The original budget for the sea lice and farm escapes element of the work was estimated at €82,911. The costing will be spread over 2023 and 2024. To date the costs for the expert meeting in 2023 have been paid in full and the Canadian Centre for Evidence-Based Conservation at Carleton University has received €13,500 out of a total budget for its workpackage of €27,000.

Description	Cost Estimates (€)	Details	Expected budget drawdown
<i>Costs for Expert Meeting</i>	19,411	Costs associated with travel & accommodation for Workshop, February 2023, Edinburgh	Paid February 2023
<i>Search term development and literature review, Data extraction & analysis</i>	27,000	Costs of data extraction and applying critical appraisal tool, Costs for standard search term development	Partly paid October 2023
<i>Writing of manuscript, sea lice</i>	15,000	Writing and project co-ordination	Summer to autumn 2024
<i>Writing of manuscript, genetic introgression</i>	15,000	Writing and project co-ordination	Summer to autumn 2024
Publication fee (e.g. Nature/ Science/Science advances)	6,500	Costs for publication of paper in high-ranking journal	Mid to late 2024
Total Estimated Cost	82,911		

EU Grant Funding to support Project Costs

At a NASCO Heads of Delegation meeting in late January 2023, discussion took place that members of the State of Knowledge Expert Group will have considerable hidden costs in staff time spent on the project which their institutions will have difficulty in covering. Following the Heads of Delegation meeting, the Expert Group was made aware by the NASCO Secretariat that the EU, through DG MARE, may be able to make funding available to support the State of Knowledge project. This resulted in NASCO entering into an agreement from 1 November 2023, for 12 months, to implement a research project in relation to ‘IMPAS – Contribution to the study of the genetic introgression and sea lice impact on wild Atlantic salmon’ to be funded by a grant received from the European Commission. This grant aid will provide 80% of €29,221.70 for the genetic introgression project and 80% of €33,234.20 for the sea lice project.

Ongoing Work on the State of Knowledge Papers

Work will continue on the level of genetic introgression of farmed salmon in wild Atlantic salmon stocks throughout early 2024 to produce a distribution map across the whole North Atlantic range, with a draft ready for June 2024, leading to provision of a draft paper on genetic introgression by October 2024. Work is continuing on the systematic review and critical appraisal of the impact of sea lice on wild Atlantic salmon with a view to having a quantitative analysis and initial draft paper in mid-2024.

Secretary and Expert Group Co-ordinator
Edinburgh
17 May 2024