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AN OVERVIEW OF THE CRITICAL APPRAISAL TOOL (CAT) PROCESS AND THE PEER-REVIEW OF A PROTOCOL FOR A SYSTEMATIC MAP TO ADDRESS "WHAT ARE THE EFFECTS OF SEA LICE FROM NET-PEN SALMON FARMS ON WILD PACIFIC SALMON IN BRITISH COLUMBIA?"– PHASE 1

Net-pen along the coast of British Columbia (photo credit: DFO).

Figure 1. Sockeye salmon, Oncorhynchus nerka.(photo credit: DFO).

CONTEXT

Fisheries and Oceans Canada (DFO), under the Sustainable Aquaculture Program, is committed to delivering science-based decision making related to sustainable aquaculture activities. The DFO Aquaculture Directorate requested Canadian Science Advisory Secretariat (CSAS) peer-reviewed science advice on the impacts of sea lice from salmon farms to wild Pacific salmon species in British Columbia (BC).

To develop the science advice, DFO is collaborating with the Canadian Centre for Evidence-Informed Conservation (CEIC, formerly Centre for Evidence-Based Conservation) at Carleton University with the overall goal of completing a systematic review to generate a state of knowledge paper on the impacts of sea lice from net-pens (traditional flow-through containment systems) on wild and enhanced salmon. Pacific salmon in BC includes wild salmon as defined in the Wild Salmon Policy and enhanced salmon. The systematic review will be delivered in three separate phases through three CSAS scientific peer review processes.

The focus of the first phase (current) meeting was to peer-review a protocol for a systematic map, which will provide a collated summary of the existing body of scientific studies addressing the primary research question "What are the effects of sea lice from net-pen salmon farms on wild Pacific salmon in British Columbia?", outlining the scope and evidence base for the rest of

the review. This first CSAS meeting will also provide an overview of the development of the Critical Appraisal Tools (CATs) to be used in the production of the systematic review.

Phase II will involve the development of CATs and the project plan for the next phase. A CAT is used to assess studies for how reliable they are in answering the specific question posed for a systematic review. In Phase III, the CATs will be used for the development and production of a peer-reviewed, evidence-based synthesis on one or more subsets of the broader systematic map question related to the impacts of sea lice (Lepeophtheirus salmonis and Caligus clemensi) from salmon farms on wild Pacific salmon in BC.

This Science Advisory Report is from the November 26-28, 2024, national peer review Overview of Critical Appraisal Tool (CAT) Process and the Peer-Review of a Protocol for a Systematic Map to Address “What are the Impacts of Sea Lice from Net-Pen Salmon Farms on Wild Pacific Salmon in British Columbia?”– Phase 1.

SUMMARY

- Sea lice have been linked to effects on wild salmon. However, there remains uncertainty about the contribution of salmon farms to those effects. The current peer review process reviewed a protocol to develop a systematic map that will be used to address the primary question, “What are the effects of sea lice from net-pen salmon farms on wild Pacific salmon in British Columbia?” A systematic map is an approach that systematically and transparently collects and describes the abundance and distribution of research effort (i.e., research papers and grey literature), and identifies groups of information (evidence clusters) and knowledge gaps. An evidence cluster is a group of studies or cases investigating a similar topic within the broader primary question.
- The overarching process consists of three phases, culminating in a systematic review(s). The development of a systematic map in Phase I involves searching specialist websites and databases using relevant, pre-defined, and specific search terms. The retrieved records are then screened using pre-defined eligibility criteria for inclusion in ongoing analysis. This process ensures transparency, repeatability, and rigour.
- The systematic map will provide a collated broad summary of the existing scientific information to assess the effects of sea lice belonging to the genera *Lepeophtheirus* and *Caligus* on five species of Pacific salmon (Chinook, coho, chum, sockeye, and pink). The systematic map will include lice on wild, enhanced, and farmed Pacific and Atlantic salmon globally to ensure that the most relevant studies are available in determining evidence clusters for the systematic review(s).
- Once the systematic map is assembled, areas where sufficient evidence exists (evidence clusters) to enable systematic review(s) will be identified. As part of the subsequent systematic review(s), the prioritized evidence clusters will be critically appraised to assess the bias and potential ability of each piece of information to address the primary question.
- For the systematic map, species of salmon and sea lice will initially be considered separately. Ideally, an evidence cluster will be defined as a group of at least twenty-five similar cases but could be as low as three. If few evidence clusters emerge with more than three cases, species will be grouped. At a minimum, cases will be divided by Pacific and Atlantic salmon, and the sea lice genera of *Lepeophtheirus* and *Caligus*.

This scientific peer review process provided peer review of the systematic map protocol, and set out directions for the next two phases to address the primary question including:

1. Searching for information on farmed and wild Pacific and Atlantic salmon globally.
2. Searching all species of the sea louse genera, *Lepeophtheirus* and *Caligus.*
3. Considering the inclusion of studies beyond the languages of English and French.
4. Guidance on what will constitute an evidence cluster in the subsequent systematic review.

INTRODUCTION

Sea lice refers to a number of naturally occurring parasitic copepod species found worldwide in ocean waters including off Canada's Atlantic and Pacific Coasts (Beamish et al., 2009; Beamish and Jones, 2011). The mechanism of attachment and feeding activities of sea lice can cause damage to the host's mucosal and skin layers and create open wounds on the host. Damage caused by sea lice can increase the host's susceptibility for co-infection from other pathogens, cause osmotic and other stress, influence behavior and growth, and in some cases lead to death of the host (Johnson et al., 1996; Mages and Dill, 2010; Krkošek et al., 2011; Sutherland et al., 2011; Brauner et al., 2012; Godwin et al., 2015; Long et al., 2019). Sea lice infestations on marine salmon farms present an ongoing challenge to the aquaculture industry and regulators globally, in terms of managing farmed fish health and minimizing the potential negative impact on wild salmon populations and the ecosystems. Sea lice on salmon farms have been associated with infestations in wild salmon (Krkosek et al., 2006; Marty et al., 2010; Peacock et al., 2013), and sea lice have been shown to have negative health and survival effects on both farmed and on wild individual salmon (Johnson et al., 1996; Mages and Dill, 2010; Sutherland et al., 2011; Brauner et al., 2012; Godwin et al., 2015; Long et al., 2019). There remains uncertainty however, about the negative effects of sea lice from salmon farms on wild salmon populations.

The current peer review process aims to develop a systematic map protocol that will capture global information on sea lice infestations in Pacific and Atlantic salmon. This broad scope systematic map will be used to wholistically address the specific request of DFO "What are the effects of sea lice from net-pen salmon farms on wild Pacific salmon in BC?"

The systematic map will be used to identify groups of information (*evidence clusters*) and *knowledge gaps* (relevant areas where scant or no collected evidence yet exists). The systematic map approach provides a means to systematically and transparently collect and describe the abundance and distribution of research effort (James 2016 and Haddaway 2016). This systematic map will provide an indication of whether if it is possible to qualitatively or quantitatively assess the effects of sea lice on wild salmon by identifying evidence clusters related to the following sub-priority questions of interest to produce a systematic review:

1. How and to what extent do sea lice affect the performance of juvenile Pacific salmon?
2. Do sea lice (from wild and farmed sources) have a population-level effect on wild Pacific salmon, and if so, to what extent?
3. To what extent do net-pen salmon farms contribute to the sea louse loads on wild Pacific salmon?

The following documents and supplementary information were reviewed to provide advice:

- What are the effects of sea lice on wild and farmed Pacific and Atlantic salmon? A systematic map protocol (Peiman K.S. et al., In prep)
- Supporting Information 1: Roses Systematic Map Protocol form
- Supporting Information 2: Search String Scoping
- Supporting Information 3: How to define an evidence cluster?

The above documents were reviewed and used to meet the remaining objectives of the meeting, specifically:

- Peer review of the systematic map protocol, and
- How to define (*a priori*) what will constitute an evidence cluster.

ASSESSMENT

What are the effects of sea lice from net-pen salmon farms on wild and farmed Pacific salmon and Atlantic salmon? A systematic map protocol

Components of the Primary Questions

The Population Exposure Comparator Outcome (PECO) components were used to develop the primary and sub-priority questions and to form the inclusion and exclusion criteria of the literature for the development of the systematic map. See (Peiman K.S. et al., In prep) for further detail on the PECO components.

The Population component will include five species of wild, enhanced, or farmed Pacific salmon (Chinook *O. tshawytscha*, coho *O. kisutch*, chum *O. keta*, sockeye *O. nerka*, and pink *O. gorbuscha*) and Atlantic salmon (*Salmo salar*) globally. The consensus at the peer review meeting was to add Atlantic salmon to the Population component to ensure that all relevant scientific studies are included for the subsequent systematic map in Phase II and potentially for future systematic review(s) in Phase III. It is anticipated that the amount of information on Atlantic salmon globally (i.e., from outside of the Pacific Ocean) will be substantially larger in volume and broader in study design than what is available on Pacific salmon species, and thus Atlantic salmon information may require appropriate handling during critical appraisal and systematic review.

The Exposure component will examine whether the Population has been exposed to sea lice in the genera *Lepeophtheirus* or *Caligus*. Any studies that include any of the five Pacific salmon species or Atlantic salmon being exposed to any species of *Lepeophtheirus* or *Caligus* will be included in the systematic map, however it is noted that the two species of interest in British Columbia are the salmon louse *Lepeophtheirus salmonis (subspecies oncorhynchi)* and the generalist herring louse *Caligus clemensi*.

The Comparator component describes studies that include a comparison of a group exposed to sea lice to a group not exposed to sea lice. Studies without a comparator will still be included in the systematic map.

The Outcome will include any outcome measurement related to adult salmon abundance (e.g., escapement, abundance, density, catch per unit effort (CPUE)), reproduction (e.g., spawning success, migration success), productivity (recruit-per-spawner), or the

proportion of adult returns in relation to the number of out migrating smolts from experimental release studies; metrics at any life stage related to

1. performance (e.g., growth, physiology, behavior, histology, infection, gene expression, predation risk, individual survival),
2. population-level survival, or
3. sea lice infestation levels; measures of species-level differences in susceptibility to lice; or surrogates thereof for any of the above.

Searching for articles and search string

The proposed systematic map will follow standards and guidelines from the Collaboration for Environmental Evidence (CEE (2022) and the reporting standards from ROSES (Haddaway et al., 2018).

This systematic map will be constructed from results of searches for scientific studies and will capture evidence available in scientific journals and grey literature (i.e., published and unpublished scientific evidence, and studies found other than in scientific journals). Peiman K.S. et al. (In prep) describes the websites, databases, and libraries that will be used to conduct the searches. A grey literature call-out through relevant mailing list and social media was performed to reach a broad audience and thus maximize the possibility of gathering all available scientific studies related to the primary question. Following peer review of the protocol, a grey literature call-out will be re-distributed (with an extended submission date) to include the revised scope of Pacific and Atlantic salmon globally and to include all lice species in the genera *Lepeophtheirus* and *Caligus*.

The search will be updated to reflect the addition of Atlantic salmon and the screening criteria will be updated to include Atlantic salmon, the global range of Pacific salmon, and the lice genera of *Lepeophtheirus* and *Caligus.* The search strings used for the Web of Science database can be found in Peiman K.S. et al. (In prep).

The eligibility screening of all the available scientific studies will be conducted at two stages:

1. title and abstract, and
2. full text.

Each stage will include a consistency check with at least 90% agreement between two reviewers. A consistency check reduces bias from one individual; however, each reviewer brings in their own unconscious biases.

Studies in English or French will be included, and consideration will be given to translating studies in other languages.

Eligibility criteria

All articles will be screened according to the predefined criteria based on the PECO components above and will only be included in the systematic map when all criteria are met. The full inclusion and exclusion criteria can be found in Peiman K.S. et al. (In prep). A list of studies excluded at full text will be provided in an additional file together with the reason for their exclusion.

Data coding and extraction strategy

Scientific studies retained as eligible after screening at the full-text level will have basic data extracted in the following categories:

1. bibliographic information;
2. study location;
3. study design details;
4. population details;
5. intervention/exposure (e.g., species of sea lice); level of exposure/infestation (e.g., number of sea lice on farmed fish, number of fish on farms, number of farms);
6. comparator details (e.g., no exposure to sea lice); and
7. outcome details.

This list may be expanded depending on the type and variety of included studies. This information will be entered into a searchable, coded database (MS-Excel).

Study Mapping

Eligible studies collected from all sources (websites, grey literature, search engines, and databases) will be mapped with visual heat maps to identify evidence clusters sufficient to allow a full systematic review, and knowledge gaps which can inform future research needs.

Narrative synthesis and descriptive statistics will be used to capture and communicate key characteristics of the evidence base (e.g., number of publications, focal salmon and lice species, life stage of salmon and lice, study objectives, exposure and comparator details, outcomes, and study designs).

How to Define an Evidence Cluster?

One of the main benefits of using a systematic map approach is that it allows for the identification of *knowledge gaps* to inform future research needs and *evidence clusters* (areas of the evidence base that are sufficiently covered by existing studies) to allow a full systematic review. Evidence clusters are groups of studies or cases from the literature that have similar populations, exposure, and outcomes. Currently there are no standards or guidelines for setting quantitative thresholds to identify knowledge clusters and gaps, leaving threshold definitions to the discretion of the subject matter expert review teams.

A lower threshold for an evidence cluster was defined for the current protocol *a priori*. For the systematic map, Atlantic salmon, the five Pacific salmon species, and the two sea lice genera, *Lepeophtheirus* and *Caligus* will initially be considered separately. An evidence cluster will be defined as a group of 25 similar cases but could be as low as three cases. If few evidence clusters emerge with more than three cases, species will be grouped. Evidence clusters that include Atlantic salmon and other sea lice species will be weighted differently than those that include the main species of interest to answer the DFOs primary request (the five wild Pacific salmon species, and the lice species *Lepeophtheirus salmonis (sp oncorhynchi)* and *Caligus clemensi)*. Given the primary question is to examine the effects of sea lice on wild Pacific salmon, the Atlantic salmon evidence gathered is intended to support a Pacific salmon analysis.

As part of the subsequent systematic review, relevant evidence clusters will be selected, and their studies critically appraised against an established set of criteria to assess their capacity to address the primary question.

Sources of Uncertainty

Both English and French studies will be included in the mapping process. Studies in other languages will be considered depending on the feasibility of the translation and potential relevance of information located during article searches.

The inclusion of Atlantic salmon in the systematic map is likely to result in a relatively high proportion of Atlantic salmon studies compared to Pacific salmon studies, and therefore the evidence on different species will need to be weighted accordingly during the selection of evidence clusters.

Despite the consistency check at both screening stages, some small degree of unconscious reviewer bias may remain.

CONCLUSION

The reviewed protocol outlines the objective of the resulting systematic map to identify, collate, and describe all relevant information relevant to address the primary question. The scope of the literature under consideration has been expanded to include wild, enhanced, and farmed Atlantic and Pacific salmon found globally, and the lice genera *Lepeophtheirus* and *Caligus.* This expansion of scope outside of literature specific to BC salmon and sea lice aims to aid in capturing a fuller understanding of what type of evaluations have been performed for salmon species, study designs, and of what outcome metrics reported in the literature can be used to address the primary question. These results are expected to help guide further exploration and analysis on the topic. The systemic map will be used to determine whether there is sufficient evidence in the literature to further investigate possible effects of sea lice from net-pen salmon farms on wild Pacific salmon (i.e., identified evidence clusters), as well as to inform management and direct future studies to fill knowledge gaps.

The mapping process is considered a necessary first step to help make evidence-informed decisions and drive more effective actions. Systematic maps provide transparent and objective identification of evidence where topics are controversial or high profile (Haddaway and Pullin, 2014), as is the case here with the impacts of sea lice on wild Pacific salmon.

After the systematic map is complete, priority evidence clusters will be critically appraised to assess the potential contribution of each piece of information in the clusters to address the primary question, and eligible priority clusters will be used to complete systematic review(s).

The literature will be mapped narratively and visually with heat maps, separating the evidence by the five Pacific and one Atlantic salmon species and the sea lice genera *Lepeophtheirus* and *Caligus* at a minimum. An evidence cluster will be defined as a group of twenty-five similar cases but may be as low as three. If few evidence clusters emerge with more than three cases, species will be grouped and, in such case, evidence pertaining to Atlantic salmon (as a species non-native to the focal area of the primary question) will require appropriate handling during critical appraisal and systematic review.

OTHER CONSIDERATIONS

The addition of the extra information from including Atlantic salmon, including Pacific salmon outside their native range, and including the effects of lice on farmed salmon will extend the search period and result in some delays to the production of the results and analyses for the subsequent phases, which are meant to inform decision-making.

Evidence-based Alternate Interpretations

It was the view of some meeting participants that the literature search for the systematic map should be limited to Pacific salmon species in their natural range exposed to *Lepeophtheirus salmonis* and *Caligus clemensi*, and not include Atlantic salmon studies. Regardless of what is found in the extended searches, that information will be irrelevant to address the primary and sub-priority questions because the different species or subspecies of sea lice have different virulence, and as different salmon species have different life histories and susceptibilities that are not specific to the British Columbia context. Therefore, the use of Atlantic salmon and Atlantic Ocean subspecies or species of lice are not appropriate proxies for assessing harm to juvenile wild Pacific salmon.

While acknowledging these concerns, the consensus decision was to expand search terms as described. Best practices in the field of wildlife health call for a wider range of evidence from host-pathogen systems that are similar in species and ecosystems. The inclusion of Atlantic salmon will provide information on another species also experiencing effects from sea lice and will allow the inclusion of studies that measure lice solely on farmed salmon in British Columbia and elsewhere. Any concerns arising from the inclusion of more studies can be addressed in subsequent phases of the review. While extrapolation from other species of salmon and their parasites should be done with extreme care, consensus was reached regarding the addition of this information as it increases the likelihood of additional knowledge relevant to the assessment of effects of sea lice from farmed salmon in BC being included in the process.

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