

	<p><b>Scientific Advisory Group of the International Atlantic Salmon Research Board</b></p> <p><i>Report of the Technical Evaluation of the ‘Developing an International Atlantic Salmon Modelling and Management Initiative’</i></p>	<p><b>SAG(21)05</b></p>
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***Report of the Technical Evaluation of the ‘Developing an International  
Atlantic Salmon Modelling and Management Initiative’***

***22 and 25 October***

***By Video Conference***

**1. Opening of the Meeting**

1.1 The Chair of the Scientific Advisory Group (SAG), Peder Fiske (Norway), opened the meeting. He welcomed members of the SAG and thanked them for agreeing to undertake the work assigned to them. He provided the following background to the technical evaluation of the ‘Developing an International Atlantic Salmon Modelling and Management Initiative’.

1.2 At the 2020 Annual Meeting of the International Atlantic Salmon Research Board (the Board) it was agreed that the SALSEA Track Programme be closed, [CNL\(20\)12](#). The Board also agreed that:

*‘any successor to SALSEA-Track should have the following attributes: be problem focused with a clearly defined internationally relevant question, which is not solely developed based on the newest technology available; have clear SMART objectives; have clear timelines; have a clear budget; be at the basin-scale; and have an identified owner / co-ordinator. Additionally, it should address issues such as: data gaps / climate change / commonalities across the jurisdictions / mechanisms for supporting new technologies.’*

1.3 It was proposed that Board members could canvass colleagues on a potential successor to SALSEA-Track if the ROAM programme was not deemed a feasible candidate successor. The Board also recognised that the process of considering a new programme could happen alongside developments in the ROAM programme. The Secretariat, therefore, asked Board Members whether they were aware of any potential successor programmes to SALSEA-Track in advance of the 2021 Annual Meeting. In response, a project proposal on ‘Developing an International Atlantic Salmon Modelling and Management Initiative’ (ISMMI) was provided. Information on this proposal and the ROAM programme is contained in paper ‘A Potential Successor to SALSEA-Track’, [ICR\(21\)07](#).

1.4 At the 2021 Annual Meeting of the Board, the ISMMI was presented by the NGO representative, Ken Whelan, [ICR\(21\)12](#). In response, the Board agreed that:

- it would refer the proposal to the SAG for a technical evaluation;
- individual SAG members could consult with other relevant experts on this evaluation;
- the SAG would be asked to address their Terms of Reference and report their technical evaluation to the Board; and
- the Board would consider this evaluation and, if necessary, a virtual inter-sessional meeting of the Board could be arranged.

1.5 The Chair noted, therefore, that the purpose of the meeting was to address the Terms of Reference and to report to the Board.

1.6 A list of participants of the SAG is contained in Annex 1.

## **2. Adoption of the Agenda**

2.1 The SAG adopted its Agenda, SAG(21)04 (Annex 2).

## **3. Consideration of the Terms of Reference**

3.1 The Group discussed the Terms of Reference for the technical evaluation, [SAG\(21\)02](#), which are as follows:

1. Provide a technical scientific evaluation of the ISMMI related to its merit, worth and significance, including, but not restricted to, an evaluation of the proposal in relation to:
  - its clarity;
  - its quality of research design and methods;
  - its originality and potential contribution to scientific knowledge;
  - its scientific ambition and probability of success;
  - its scientific outputs, dissemination and potential scientific impact.
2. Provide additional technical scientific information which will assist the Board in determining:
  - the relevance of the proposal to the purpose of the Board, i.e. ‘to promote collaboration and co-operation on research into the causes of marine mortality of Atlantic salmon and the opportunities to counteract this mortality.’
  - the relevance of the proposal to the required attributes for a successor to SALSEA-Track, i.e. be problem focused with a clearly defined internationally relevant question, which is not solely developed based on the newest technology available; have clear SMART objectives; have clear timelines; have a clear budget; be at the basin-scale; and have an identified owner / co-ordinator. Additionally, it should address issues such as: data gaps / climate change / commonalities across the jurisdictions / mechanisms for supporting new technologies.
3. Provide additional technical scientific information which will assist the Board in its consideration regarding endorsement of the proposal.

## **4. Provision of a Technical Scientific Evaluation of the ‘International Atlantic Salmon Modelling and Management Initiative’ (ISMMI)**

### **General Comments**

4.1 The Chair referred participants to the ISMMI proposal (Annex 3) and the presentation made by Ken Whelan at the Board’s 2021 Annual Meeting, [ICR\(21\)12](#). Dr Fiske gave a short presentation of his understanding of the proposal. This was followed by a general discussion of the participants’ views of the proposal.

4.2 The SAG agreed that it was broadly supportive of the concept of additional investigations into the marine ecology of the species and would welcome the development of an international funding bid. It also acknowledged the excellent scientists involved in the proposal. The broad discussion related to a number of general issues.

- 4.3 There was agreement amongst members of the SAG that the proposal was difficult to review. It was unclear whether the SAG should provide a technical scientific evaluation of the £96 K request to the Board, which was primarily focused on preparing a large multi-year project proposal, or the potential larger multi-year project. Much of the proposal's text focused on the need for that larger effort.
- 4.4 Given that the £96 K request to the Board was largely to support the preparation of a larger multi-year proposal, it was impossible to evaluate the likelihood of success without having a clear understanding of the details of the targeted funding call. The SAG agreed that it was impossible to ensure that a potential funding opportunity would align with the proposal development and submission timeline outlined within the ISMMI proposal.
- 4.5 Further, there was agreement amongst members of the SAG that the submitted proposal lacked detailed scientific content. This prevented the SAG from providing a complete technical scientific evaluation against the criteria set out in its Terms of Reference.

#### **Clarity**

- 4.6 As set out in the Terms of Reference, the SAG discussed the clarity of the ISMMI. The SAG welcomed the ISMMI's intention to use the Life Cycle Model to explore the wider ecosystem related to wild Atlantic salmon and the use of the Life Cycle Model to investigate Atlantic salmon in the ocean. However, it noted an overall lack of clarity and felt there were few scientific examples or concrete proposals for the SAG to provide a technical evaluation of.
- 4.7 The SAG also noted the lack of supporting evidence behind many of the statements made within the proposal while attempting to build a case on the need for the proposed work. As an example, the proposal states that work would address 'alignment of existing salmon stock assessment and management models, realising the potential for improving biological realism in existing models' (page 8). However, the SAG noted that this alignment may not be a critical need given that the Greenland fishery is a small single species fishery and that the current assessment models have proven to be exceptionally robust according to ICES evaluations. Additionally, the SAG identified a lack of information against which to assess the statement that 'a direct benefit of refining the biological realism of models used at WGNAS and their integration with new modelling approaches, would be an improvement in PFA forecasts and the NASCO framework of indicators.' The SAG noted that the proposal blends the stock assessment and catch advice efforts undertaken by ICES and the marine ecology investigations undertaken by various scientists. Framing these two separate efforts as one confused the proposal and made it difficult to review.
- 4.8 The SAG considered the different groups mentioned in the ISMMI. It would have wished to have a clearer understanding of the roles and links between the groups involved, including the WKSalmon workshop participants and those involved in the Missing Salmon Alliance and the Likely Suspects Framework. The SAG would also have liked to see a clearer description of the expected role of the Board within the project.
- 4.9 The SAG noted that the proposal would have benefitted from more detail in a number of areas such as: how the 'need for a paradigm shift' was determined; whether freshwater ecology was to be included in the modelling since it impacts upon salmon survival at sea; who the 'ad hoc' group of scientists mentioned in the proposal are; the identity of the 'end user' and the 'salmon managers' in the proposal; and who the decision support framework would be built for.

### **Quality of Research Design and Methods**

- 4.10 The SAG discussed the quality of research design and methods of the ISMMI. It agreed that it was unable to provide a technical scientific evaluation against this criterion since detailed information on this was not included in the proposal. Participants acknowledged that comprehensive information on research design and methods would likely be included in the future international funding bid; however, as noted above, at this stage the SAG was tasked with evaluation of the ISMMI proposal only.

### **Originality and Potential Contribution to Scientific Knowledge**

- 4.11 The SAG discussed the originality and potential contribution to scientific knowledge of the ISMMI. The SAG was unable to evaluate the submitted proposal against this criterion as it lacked technical detail in this regard. However, the SAG agreed that the future international funding bid (if successful) may have considerable potential in terms of originality and contribution to scientific knowledge.

### **Scientific Ambition and Probability of Success**

- 4.12 The SAG discussed the scientific ambition and probability of success of the ISMMI. The SAG noted that success was highly likely in terms of funding the attendance of experts at workshops and developing an international funding bid as stated. It also noted that the ISMMI appears to be very ambitious given that the current Life Cycle Model has not yet been benchmarked by ICES or implemented for advice. However, the excellence of the scientists involved improved the probability of success. The SAG discussed a number of areas that it considered would be challenging and may affect outcomes:

- getting enough good quality data to feed into the model may be a challenge;
- the international funding bid and associated project would address very challenging issues that scientists are struggling with globally. Making progress in these very complex areas would be a significant and difficult task; and
- the ultimate success of the ISMMI would lie in whether the proposed international funding bid was successful. This may depend on wider factors such as the requirements of funding streams, such as Horizon2020, open at the time. The SAG noted that these funding streams are very competitive and projects need to be in line with the requirements at the time of submission.

### **Scientific outputs, dissemination and potential scientific impact**

- 4.13 The SAG discussed the scientific outputs, dissemination and potential scientific impact of the ISMMI. It noted that if the future international funding bid was successful, this was likely to have a high impact in terms of scientific output and impacts. However, the SAG concluded that there was insufficient detail about the scientific outputs in the proposal to be able to provide a technical scientific evaluation against this criterion. For example, within the ISMMI, it was noted that a User Interface (UI) Decision Support Tool would be created, which certainly could be counted towards increased scientific outputs, dissemination and potential scientific impact. However, the details regarding the tool, what it may look like, what it may communicate, who it was aimed at and what problem it is intended to improve upon were lacking.

## **5. Provision of Additional Technical Scientific Information**

### **Relevance of the Proposal to the Purpose of the Board**

- 5.1 The Chair reminded participants that the Terms of Reference asked the SAG to provide additional technical scientific information which would assist the Board in determining

the relevance of the proposal to the purpose of the Board, i.e. *‘to promote collaboration and co-operation on research into the causes of marine mortality of Atlantic salmon and the opportunities to counteract this mortality.’*

- 5.2 The SAG agreed that the proposal has relevance to the purpose of the Board in that it promotes collaboration in research related to marine mortality at sea. However, it noted that, at present, only European scientists are involved. The SAG would encourage greater collaboration across the entire North Atlantic within the proposal whilst acknowledging the difficulties this might create for obtaining funding, for instance through the EU’s Horizon2020 programme.

### **Relevance of the Proposal to the Required Attributes for a Successor to SALSEA-Track**

- 5.3 The Chair reminded participants that the Terms of Reference asked the SAG to provide additional technical scientific information which would assist the Board in determining the relevance of the proposal to the required attributes for a successor to SALSEA-Track. The SAG agreed that, although it was not clear what the SAG was being asked to evaluate, many components identified within the ISMMI proposal, for both the one-year pilot and the multi-year project, did appear to meet many of the required attributes.
- 5.4 However, the SAG agreed that more clarity was required to enable the proposal to be fully evaluated according to the SALSEA-Track replacement criteria. The SAG also noted that (as mentioned above) the geographical extent of the collaboration would need to be expanded to better meet the ‘basin-scale’ attribute. Participants noted confusion regarding the owner / co-ordinator of the ISMMI and questioned the proposed role of the Board, in relation to this initiative, and whether the Board would agree to it.
- 5.5 Overall, the SAG agreed that it was unable to adequately evaluate the ISMMI against the attributes for a successor to SALSEA-Track given many of the issues raised above.

## **6. Consideration of any other additional technical scientific information to assist the Board in its decision to endorse the proposal.**

- 6.1 The Chair asked participants if they wished to provide any additional technical scientific information to assist the Board in its consideration regarding endorsement of the proposal. The SAG noted that it was broadly supportive of the research in the ISMMI and the proposal to develop an international funding bid. However, it agreed that the SAG was unable to provide additional technical scientific information to assist the Board in its consideration regarding endorsement of the proposal, given the numerous issues identified above.

## **7. Other Business**

- 7.1 The SAG was updated on progress made in connection with the Pop-off Satellite Tag (PSAT) programme at Greenland and the ROAM Programme under this Agenda item.
- 7.2 The SAG was advised that the PSAT tracking programme at Greenland had been very successful in 2021. Seventy tagged fish were released during the period from mid-September to the beginning of October, an increase from 12 tagged fish released in 2018 and 25 tagged fish in 2019. This increase was apparently due to a combination of good fishing in Greenland in 2021 and adjustments to fishing techniques from those used in the past. Preliminary information was available on 40 of the 70 total tags deployed; to date only four out of the 40 had popped off, all of which were located in the central Labrador Sea. The SAG was also advised that genetic samples had been taken from all 70 tagged fish to enable the identification of their region of origin.

- 7.3 The SAG was advised that successful field trials had taken place in 2021 in the ROAM programme. During the trial, two receivers had been deployed off the continental shelf south-east of Cape Cod. The trial was conducted in two parts: ROAM tags attached to various deployed oceanographic monitoring equipment; and ROAM tags attached to a glider which was deployed over a number of weeks. The glider was able to behave like a salmon, diving to depths and returning to the surface. Preliminary available data showed that the tags deployed on the oceanographic equipment had recorded very strong signals from 15 – 20 km away and had recorded faint but identifiable signals from up to 500 km away. The tags attached to the glider also appeared to work extremely well, picking up signals 70 km away at a depth of 200 m. The results are all preliminary and data analysis is ongoing.

## **8. Report of the Meeting**

- 8.1 The SAG agreed the report of its meeting.

## **9. Close of the Meeting**

- 9.1 The Chair thanked participants for their contributions and closed the meeting of the SAG.

*List of Participants*

**Canada**

\*Julien April

**European Union**

\*Jaakko Erkinaro

**Norway**

\*Peder Fiske (Chair)

**Russian Federation**

\*Sergey Prusov

**United Kingdom**

\*Dennis Ensing

**United States**

\*Tim Sheehan

**NGO Representative**

Dave Meerburg

**Secretariat**

Wendy Kenyon

Louise Forero

\*Nominated SAG Member

**SAG(21)04**

***October 2021 Ad Hoc Meeting of the Scientific Advisory Group of the  
International Atlantic Salmon Research Board***

***By Video Conference***

***22 and 25 October 2021***

***Agenda***

1. Opening of the Meeting
2. Adoption of the Agenda
3. Consideration of the Terms of Reference, SAG(21)02
4. Provision of a technical scientific evaluation of the ‘International Atlantic Salmon Modelling and Management Initiative’ (ISMMI)
5. Review and provision of additional technical scientific information to inform the Board as to whether:
  - the ISMMI is consistent with the Board’s purpose; and
  - the ISMMI is fully in line with the agreed attributes for a successor to SALSEA-Track.
6. Consideration of any other additional technical scientific information to assist the Board in its decision to endorse the ISMMI proposal.
7. Other Business
8. Report of the Meeting
9. Close of the Meeting



## Developing an International Atlantic Salmon Modelling and Management Initiative (ISMMI)



### Executive Summary

Over the past four years NASCO/the International Atlantic Salmon Research Board (the Board) has actively supported the development of the Likely Suspects Framework (LSF) (ICR(20)11). The NASCO/ICES advisory group (WGNAS) has supported the development of a comprehensive Life Cycle Model (LCM). The scientists involved in developing these initiatives held a series of meetings over recent months to see how best to integrate and utilise the results from these two programmes, to better inform advice and guidance to ICES and NASCO on the pressures facing salmon populations. The ad-hoc group concluded that a future vision for international salmon conservation and management must move beyond the provision of catch advice based on single-species demographics to an ecosystemic vision. This approach recognises the changes in the ecosystem that impact on salmon during the marine phase and tackles the urgent and fast moving challenges facing salmon populations for the remainder of this century. Such changes are firmly embedded in global environmental change. A new management paradigm is required which no longer relies on estimates of population and catch advice alone but incorporates an ecosystem approach, linking models and prioritised research programmes to develop a suite of dynamic ecosystem indicators and integrated assessment methods.

For the ICES Atlantic salmon advice to become more closely aligned with the recognised benefits of using an ecosystems-based approach, the stock assessment methodology for salmon will require further model development and benchmarking. For example, the current iteration of the Life Cycle Model, being tested by the WGNAS in 2021, will be benchmarked in the near future. However, the LCM as it currently stands contains many assumptions around the growth and survival of salmon at sea and there is no doubt that it would greatly benefit from the inclusion of relevant marine ecosystem data. It is now clear that for future benchmarking, what is required is a portfolio of models that include both marine environmental and marine ecosystem indicators. Such an approach, we would argue, would directly support the work of WGNAS and more closely align future benchmarking of Atlantic salmon assessments with the ICES processes for other marine species. We believe that this could be achieved by linking the LSF and the LCM-related approaches.

### Better Integrating Modelling and Management

Our proposal offers an opportunity to improve the biological realism of existing modelling approaches. It would allow for their integration to support the development of ecosystem and evolutionary based

enhanced guidance/advice that would go beyond that presently available for Atlantic salmon. Managers at national/area/local levels would benefit from access to enhanced guidance, while the underlying advice processes would remain relevant to ICES/NASCO regulatory requirements.

Our future vision is for enhanced coordinated salmon management, aligned with the provision of a proposed new three-tiered management guidance/advice development addressing wider management needs:

- **Quantitative catch advice** with regard to stock complex/national conservation limits.
- **Management guidance** (soft advice), 2-5 year outlook for stocks, including impact of ocean conditions, and evaluation of impact of management measures in a wider ecosystem context.
- **Scenario modelling for managers**, exploring conditions not yet experienced, such as climate change-driven extremes and impact on stock genetic diversity and resilience, including probability of extinction in climate change-sensitive areas.

This proposed advice landscape mirrors aspects of economic forecasting, where guidance and scenario modelling tools are widely used and relayed to managers to inform policy development and decision-making.

### **What is ISMMI?**

The ISMMI initiative would initially involve a one-year pilot study to begin in 2022. This would bring the key modelling approaches and data together under the overarching Likely Suspects conceptual framework, while concurrently building an international consortium bid, spanning the three NASCO Commission areas, for a four-year science project (2023-2026) to develop the modelling and advice frameworks. Year 5 (2026) would be an implementation year, when enhanced scientific models and new management tools would be introduced to WGNAS and NASCO.

Centering on linking the work streams of the French Institut Agro/INRAE modelling groups and the MSA LSF group, the one-year ISMMI pilot programme would address four key areas:

1. Improvement of current engagement with salmon management across scales: assisting with translation and interpretation of new model outputs, leading to better alignment with salmon management requirements, for example, via novel user-friendly Decision Support Tools (DSTs).
2. Alignment of existing salmon stock assessment and management models, realising the potential for improving biological realism in existing models.
3. Progress with data mobilisation and workflow development, providing the components for a more Integrated Ecosystem Assessment based vision for salmon that integrates existing approaches and guides future modelling work.
4. Development of a major international consortium funding bid to initiate, develop and support the evolution of ecosystem-based management for Atlantic salmon.

For example, a direct benefit of refining the biological realism of models used at WGNAS and their integration with new modelling approaches would be an improvement in PFA forecasts and enhance the NASCO framework of indicators (FWI). Such an approach would also provide wider (environmental and ecosystem) indicators of the outlook for stock survival for periods of two to five years ahead, together with potential scenario modelling of longer-term changes.

## Board Request

At the 2020 NASCO Annual Meeting the Board agreed that (ICR(20)16) *“any successor to SALSEA-Track should be: problem focussed; with a clearly defined internationally relevant question; not solely developed based on the newest technology available; have clear SMART objectives; a clear timeline; a clear budget; be at the basin-scale, and have an identified owner/co-ordinator. Additionally, it should address issues such as: data gaps; climate change; commonalities across the jurisdictions and mechanisms for supporting new technologies”*.

We believe that the ISMMI Initiative, as detailed in the full proposal below, fulfills the criteria agreed at the 2020 meeting of the Board. Delivery of the suggested strategic plan would initially involve a one-year preparatory study to begin in 2022. This study would bring together the key modelling approaches and data sets, under the overarching Likely Suspects conceptual framework. It would concurrently build an international consortium bid for a four-year science project (2023-2026), to develop the modelling and advice frameworks, spanning the three NASCO Commission areas. Year five (2026) would be an implementation year, when enhanced scientific models and new management tools would be introduced to WGNAS and NASCO.

In our view the Board, working through NASCO, is ideally placed to co-ordinate such an internationally focused development. The Board is basin wide in its scope and is ideally placed to encourage Parties to embrace this new paradigm and to become full partners in the programme. The chances of success in launching a major research funding bid (*circa £3-5m*) would be considerably enhanced by the support of key inter-governmental organisations such as NASCO. We are therefore, seeking the endorsement of the Board for this initiative.

Very significant funding, both public and private sector, has been invested in the establishment of the Likely Suspects Framework research team and in the development of the Life Cycle Model (*circa £500k* to date). These human and intellectual resources will be fully available to ISMMI. We are also requesting matching support funding (£96k) from the Board and or parties to NASCO, for the one-year preparatory study to bring key modelling approaches and data together and to support the concurrent development of a major international research proposal, inclusive of all parties to NASCO.

Fundamental to the work of NASCO and ICES are improvements in scientific advice to managers and the integration of advice on salmon populations across their marine phases, with ecosystem data emanating from other relevant ICES programmes. As outlined above, we believe that a future vision for international salmon conservation and management must move beyond the provision of catch advice based on single-species demographics. It must encompass a wider eco-evolutionary vision, which recognises the speed of change in both the ocean and in our climate and which can tackle the urgent and fast moving challenges facing salmon populations for the remainder of this century. We believe that the Board is best placed to ensure the co-ordination that is required to oversee the evolution of ISMMI and to deliver on the comprehensive, 5 year, strategic plan as outlined in this proposal.

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## ISMMI - Full Proposal

### Developing an International Atlantic Salmon Modelling and Management Initiative (ISMMI)

#### Background

Over the past four years NASCO/the International Atlantic Salmon Research Board (the Board) has actively supported the development of the Likely Suspects Framework (LSF)<sup>(1)</sup> (ICR(20)11). The NASCO/ ICES advisory group (WGNAS) has supported the development of a comprehensive Life Cycle Model (LCM)<sup>(2)</sup>. The scientists involved in developing these initiatives held a series of meetings over recent months to see how best to integrate and utilise the results from these two programmes, to better inform advice and guidance to ICES and NASCO on the pressures facing salmon populations. The ad-hoc group concluded that a future vision for international salmon conservation and management must move beyond the provision of catch advice based on single-species demographics to an ecosystemic vision. This approach recognises the changes in the ecosystem that impact on salmon during the marine phase and tackles the urgent and fast moving challenges facing salmon populations for the remainder of this century. Such changes are firmly embedded in global environmental change. A new management paradigm is required which no longer relies on estimates of population and catch advice alone but incorporates an ecosystem approach and an evolutionary-based approach, linking models and prioritised research programmes. Such an approach would aim to develop a suite of dynamic ecosystem indicators, which align closely with the emerging concept of integrated ecosystem assessment (IEA). Fully supported by fisheries management efforts globally, the IEA approach provides a framework to provide management advice for fish stocks, taking account of the full array of ecosystem interactions that can influence eco-evolutionary stock dynamics.

For the ICES Atlantic salmon advice to become more closely aligned with the recognised benefits of using a more ecosystems-based approach in the assessment of other marine species it is envisaged that the stock assessment methodology for salmon will involve benchmarking, as appropriate. For example, the current iteration of the Life Cycle Model being tested by the WGNAS in 2021 will be bench marked by ICES in the near future. However, the LCM as it currently stands contains many assumptions around separating out the different sources of variability among the phases of the life cycle, in particular between survival during the first and second years at sea and their intricate relation with the maturation schedule. It lacks also an evolutionary perspective. There is no doubt that it would greatly benefit from the inclusion of relevant marine ecosystem data to better inform the drivers of variability and help identify tipping points during the life cycle most likely to be responsible for the decline in marine survival. These would both improve our understanding of the mechanisms and drivers of the historical trends (the hindcasting phase of the analysis) and strengthen our capacity to forecast future marine productivity and salmon abundance. This should be embedded within an eco-evolutionary approach where the intricate relationship between phenotypic plasticity and evolutionary response are considered to resolve the likely suspects of the response of individuals and populations to multiple anthropogenic pressures. It is now clear that for future benchmarking, what is required is a portfolio of models, which include both marine environmental and marine ecosystem data. We believe that this could be achieved by linking the LSF and the LCM related approaches.

The second of three ICES/NASCO workshops (WKSalm2 – Data Evaluation) is provisionally scheduled for 2021. The principal objective of the workshop will be to examine how best to mobilise and identify the most relevant marine ecosystem drivers; how these data can be assimilated and stored in the LSF data repository and subsequently made available to the teams refining the Life Cycle Model and other

sister models. This would include the exploration of novel data on environment and ecosystem attributes across different basins and consideration of salmon energetics during the marine phase. Such an approach, we would argue, is an essential prerequisite to moving towards a novel, ecosystem based approach to future salmon management. It would directly support the work of WGNAS and more closely align future benchmarking of Atlantic salmon assessments with the ICES processes for other marine species.

At the 2020 NASCO Annual Meeting the *International Atlantic Salmon Research Board* agreed that (ICR(20)16):

2) Any successor to SALSEA-Track should have the following attributes:

- be problem focused, with a clearly defined internationally relevant question, which is not solely developed based on the newest technology available
- have clear SMART objectives
- have clear timelines
- have a clear budget
- be at the basin-scale
- have an identified owner / co-ordinator.

Additionally, it should address issues such as:

- data gaps
- climate change
- commonalities across the jurisdictions
- mechanisms for supporting new technologies

We believe that the *International Atlantic Salmon Modelling and Management Initiative (ISMMI)*, as outlined below, fulfills the criteria agreed at the 2020 meeting of the Board (Table 1). We are, therefore, seeking the endorsement of the Board for this initiative and are also requesting matching support funding of £96k from the Board and /or parties to NASCO for one year to allow for the development of a major international research proposal, inclusive of all parties to NASCO.

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<sup>1</sup> The Likely Suspects Framework (LSF) is the flagship project of the Missing Salmon Alliance (MSA), and represents the development of a guiding vision for actions to help boost adult Atlantic salmon returns. It will enable salmon managers to adopt an adaptive management approach and to make evidence based decisions. The LSF will provide salmon managers with access to high quality information on the causes of mortality variation. A detailed understanding is required of the mechanisms driving variation in salmon stock abundance and this objective is at the very heart of the LSF process.

<sup>2</sup>The Atlantic salmon Life Cycle Model, led by researchers Institut Agro and INRAE (France), provides an integrated hierarchical Bayesian life cycle model that simultaneously estimates the abundance of post-smolts at sea, post-smolt survival rates, and proportions maturing as 1SW, for all SU (stock units) in Northern Europe, Southern Europe and North America. The model is an age- and stage-based life cycle model that considers 1SW and 2SW life history strategies and harmonises the life history dynamics among SU in North America and Europe

**Table 1 Outline and scope of Year One ISMMI proposal**

ISMMI Programme area	Problems addressed	Objectives	Board matching funding requested
1.Improved engagement with salmon management across scales, assisting with translation of new model outputs better aligned to salmon management via Decision Support Tool/s	Issues with communication and integration of important research and modelling outputs into management actions	<b>Specific</b> To provide a User Interface (UI) Decision Support Tool <b>Measureable</b> Quantifiable use-data and metrics from engagement with UI Interface <b>Achievable</b>	£12K  Time and travel for keynote participation at one workshop plus rapporteur and organisation

	Recognised issues with the poor flow between ICES/NASCO stock assessment advice and regional and local management teams / stakeholders	Phase 1 development of UI underway and technical expertise within network of proposers <b>Relevant</b> Salmon managers need better access to good management advice and forecasting tools <b>Time bound</b> A functional UI to provide decision support is deliverable within 1 year, with iterative revision and refinement necessary via continued management	
2.Alignment of existing salmon stock assessment and management models, realising the potential for improving biological realism in existing models	Current restricted forecasting capacity in PFA models  Difficulties linking modelling to the NASCO framework of indicators (FWI).  Individual models can represent important life-stage-specific survival variation differently, and include evolutionary processes	<b>Specific</b> Model evaluation and refinement to increase biological realism <b>Measureable</b> Documented revisions and evolution of modelling programmes <b>Achievable</b> Functional models exist and expertise within networks of proposers <b>Relevant</b> Recognised limitations in current modelling frameworks are addressed <b>Time bound</b> Development of specified elements within one year	£15k  Contribution towards travel costs for attending 2 x 2 day workshops
3.Progress towards providing the components for a more Ecosystems Based Approach for salmon management that integrates existing and guides future modelling work	Limited use of environmental and ecosystem indicators to provide biological realism in current modelling approach  Poor integration between salmon and the Integrated management approach promoted for other marine species  Limited opportunities to refine and develop modelling and stock assessment approach	<b>Specific</b> Development of IEA strategy and ecosystem indicators evaluation <b>Measureable</b> Conduct comparison between outputs from current stock assessment methods and developing IEA approach <b>Achievable</b> Multiple examples of developing IEA approach and expertise within ICES networks <b>Relevant</b> An Ecosystem-based management addresses current challenges and future requirements <b>Time bound</b> Initial IEA development will be to assemble and assess potential indicators in year 1	£35K  Contribution towards travel costs for attending 2 x 2 day data –tech workshops  Fund for partial covering WKSalmon 3 participants’ costs to increase participation
4.Development of an Atlantic, basin-wide, international funding bid to develop this initiative and support the roll out of a 5-year strategic science plan for Atlantic salmon management	Limited coordination of national salmon research programmes and efficacy of resource use  Requirement for a future vision for integrating international salmon management and research programmes	<b>Specific</b> The production and submission of an international funding bid <b>Measureable</b> Bid development provides identifiable research consortium and content will provide transferable resources/models <b>Achievable</b> Previous track record of proposers. Key groups and individuals are well integrated within proposers’ networks assisting bid development	£34K  Project bid developer, salary and travel costs contribution for 12 months involvement ~£34k

		<p><b>Relevant</b> International collaboration behind an agreed vision is required to address the scale of challenges facing Atlantic salmon</p> <p><b>Time bound</b> Bid development and submission completed within 1 year</p>	
			<b>Total £96K</b>

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### The Challenge - Integrating Modelling and Management

As outlined above our proposal offers an opportunity to improve the biological realism of existing modelling approaches and integrate them to develop ecosystem and evolutionary-based enhanced guidance/advice that would go beyond that presently available for Atlantic salmon. Through linking existing and on-going programmes of work, managers at national/area/local levels would gain benefit from access to improved guidance while the underlying processes would remain relevant to NASCO /ICES regulatory and advisory requirements.

Our future vision is for enhanced coordinated salmon management, aligned with the provision of a proposed new three-tiered management guidance/advice development addressing wider management needs:

- **Quantitative catch advice** with regard to stock complex/regional/national CLs.
- **Management guidance** (soft advice), 2-5 year outlook for stocks including ocean conditions, evaluation of impact of management measures in a wider ecosystem context.
- **Scenario modelling for managers**, exploring conditions not yet experienced, such as climate change driven extremes and impact on stock genetic diversity and resilience, including probability of extinction.

The above advice landscape mirrors some aspects of economic forecasting, where guidance and scenario modelling tools are widely used and relayed to managers, to inform policy development and decision-making.

It is widely recognised that one single over-arching stock forecasting model cannot address all requirements for integrating data on stock abundance and survival trends. Furthermore, our ability to forecast stock abundance trends for management advice purposes is highly contingent on the biological realism of the models used. Models are developed at different spatial scales and at different level of biological organisation, from individual-based models developed at the scale of populations to basin-scale models. All have pros and cons in terms of data that can be assimilated and questions that can be addressed. Developing connections among a portfolio of different models, improving biological realism in modelling approaches and exploring the potential for wider integration of ecosystem indicators to enhance the ability of ICES to provide advice on Atlantic salmon may provide a way forward. Progress may be possible via contemplating a series of models, addressing particular areas of interest but fully coupled together, rather than a single end-to-end ecosystem model.

The Likely Suspects Framework links well with the development of the work of key Life Cycle Modelling initiatives by: providing an internationally supported conceptual framework, organising key mortality

questions / data resources by life-stage, spatio-temporal domains and by management drivers. Coordinated advances in both programmes form the basis of this proposal.

### **ISMMI: a strategic plan, under the auspices of the Board**

The Board is invited to consider establishing a five-year strategic science plan as a successor to SALSEA-Track. This plan would centre on further modelling development research and data acquisition, with the primary objective of supporting a more integrated ecosystem-based approach to Atlantic salmon assessment and management: the *International Salmon Modelling and Management Initiative (ISMMI)*.

Delivery of the suggested strategic plan would initially involve a one-year pilot study to begin in 2022. This study would bring together the key modelling approaches and data sets, under the overarching Likely Suspects conceptual framework. It would concurrently build an international consortium bid for a four-year science project (2023-2026), to develop the modelling and advice frameworks, spanning the three NASCO Commission areas. Year 5 (2026) would be an implementation year, when enhanced scientific models and new management tools would be introduced to WGNAS and NASCO.

The pilot study will be critical to establish the work streams for the overall five-year plan, and in particular to support the development of the Atlantic-wide consortium bid. An element of match-funding from the Board is being requested for the pilot study, as detailed in Table 1 above.

Centering on linking the work streams of the French Institut Agro/INRAE modelling groups and the MSA LSF group, the one-year ISMMI pilot programme would address four key areas:

#### **1. Improvement of current engagement with salmon management across scales: assisting with translation and interpretation of new model outputs, leading to better alignment with salmon management outputs via Decision Support Tools (DSTs)**

In seeking to improve the effectiveness of salmon management advice, communication of the outputs from the increasingly complex models used in generating such advice urgently needs to be improved. There is a need to evolve management guidance and advice in a coordinated and focused way to meet the needs of various local national and international administrations and management groups.

An important element is communicating with salmon managers and integrating their requirements into tool development. Use of terminology is important, and great care is needed in communicating modelling functions and limitations and in expectation management. If successfully addressed, this aspect could allow improvements in the flow of ICES/NASCO stock assessment advice to stakeholders, most particularly to regional and local management teams.

Inherent to the LSF concept is the use of decision support tools (DSTs), to enhance the interface between modelling outputs and managers. These tools aim to provide user-friendly, accessible graphical type outputs to show important trends, such as abundance and survival, together with prospects for ocean survival and the status of key ecosystem indicators (e.g. predators, competitors etc.). DSTs can provide a wider lifetime context to quantitative advice and allow managers to make timely decisions, while taking account of such information. Scenario (“*what-if*” prospective) is also conceivable in the design and implementation of DSTs.

Specifically we propose to:



- Host a workshop (or series of focused discussions) with managers, to seek input to guide the development of management-friendly, easily understood interfaces between model outputs and management advice / guidance.
- On that basis, develop improved interfacing between managers and modellers, specifically testing various decision support tools structures and designs.
- Concurrently, evolve the translation of model outputs beyond current parameters to encompass stock prospects (survival outlook) and scenario planning.

## **2. Alignment of existing salmon stock assessment and management models, realising the potential for improving biological realism in existing models.**

This component would build on specific model components development/enhancement already underway:

Institut Agro/INRAE group and collaborators:

- Refining the LCM and exploring incorporating variability in the natural mortality rates (M) post-PFA, and the intricate relationship between survival and maturation schedule.
- Expanding biological and evolutionary realism beyond current LCM capacity to incorporate a wider range of life history options
- Improving synergies and connections between salmon modelling approaches (Individual Based Atlantic Salmon Modelling and LCM)
- Data workflow process to provide inputs to LCM

Likely Suspects Framework group:

- Prioritising a set of salmon mortality questions as testable hypotheses, linked to life stage and domain
- Building a structured data framework organising and mobilising environmental and ecological datasets, using Graph database technology
- Establishing a technical toolbox of salmon assessment resources to facilitate evaluation in future developments
- Phase 1 design of a user-interface web application of the mechanism to relay the results of the LSF programme to salmon managers: a Decision Support Tool

A direct benefit of refining the biological realism of models used at WGNAS and their integration with new modelling approaches, would be an improvement in PFA forecasts and the NASCO framework of indicators (FWI). Such an approach would also provide wider (environmental and ecosystem) indicators of the outlook for stock survival for periods of two to five years ahead, together with potential scenario modelling of future, and longer term, changes. This would guide managers on what underlying changes were impacting, or likely to impact, salmon survival and abundance, thus enhancing the utility of the FWI process.

## **3. Progress towards providing the components for a more Integrated Ecosystems Assessment based vision for salmon, that integrates existing approaches and guides future modelling work**

Evolving an IEA approach for salmon management will require a high level of cooperation within ICES working groups and dedicated development time. Application of an IEA for Atlantic salmon will also require considerable development to focus it clearly on critical areas of concern and to fine tune it for use.

Drawing a distinction between hind casting and forecasting approaches within an IEA framework is important. For example, available indicators (or proxies) for past changes are not always easily

integrated into methods to provide useful forecasts. However, hind casting is essential, especially in supporting an understanding of mechanistic (causal) relationships between marine indicators and salmon survival at sea. To better explain past biological and environmental conditions, hind casting models would be cooperatively focused to advance several linked areas of work:

- **New data mobilisation and workflow development to access comprehensive physical and ecological datasets:** Availability and assessment would be based initially on the inventory from WKSsalmon1. The LSF data frame is currently building a suitable data resource, organised in a global data repository (using FAIR data principles) and in collaboration with colleagues working on similar challenges in North America (Atlantic and Pacific regions). Data mobilisation and sharing will facilitate new analysis (such as break-point analysis), specifically assisting linking of modelling approaches and hypotheses testing. The LCM data workflow approach, managed by Institut Agro/INRAE, shares the principles and elements of the underlying structure. We believe that an opportunity now exists to combine these data approaches.
- **New indicator development to improve assessments:** Consideration of the extent of initial datasets is required to provide variables for integration into existing or future model refinements, as potential indicators or as proxies. One focus area involves combining hydrodynamic models delivering ocean transport information with proxies for prey distribution and abundance, derived from ecological datasets (e.g. CPR series).
- **Prioritise and coordinate the work programme around addressing key mortality questions:** An MSA-LSF led initiative to prioritise salmon mortality hypotheses, which will facilitate linkage with available datasets/indicators/proxies, is underway, providing preparatory material for the upcoming 2021 ICES WKSsalmon2 workshop. This will allow convergence between relevant datasets that are likely to be informative, leading to a tightly focused data call to the wider ICES community.

#### **4. Development of an international funding bid to initiate, develop and support the evolution of ecosystems-based management for Atlantic salmon.**

A central component of the proposed ISMMI programme will be the building of an international consortium-funding bid for a four-year Atlantic-wide science project, to fully develop the modelling and advice frameworks outlined above. This comprehensive bid for external funding (*circa* £3 - £5 million) could be targeted towards the new Horizon Europe Programme (or similar) with strong linkages to similar and complimentary funding opportunities in North America.

We envisage that by drawing together a wide range of collaborators in a cohesive and comprehensive bid for external funding, the 4-year proposal could include the four work packages below. Bid development could take advantage of the timing of the third in the series of NASCO / ICES workshops (WKSsalmon3, provisionally planned for 2022) as a checkpoint to direct, review and evaluate the content of the proposal.

- **Model development:** Model integration within the LSF top-level conceptual framework, (portfolio of models), including enhancing biological realism of candidate modelling approaches. This would support ICES benchmarking and WGNAS annual advice to NASCO.
- **Accessing and mobilising the data:** Hypotheses-led mobilisation of the data components to provide an ecosystem-based vision for future salmon stock assessment and management. Such an approach would inform and enhance future modelling work.

- **Management guidance and advice:** Directing model and data developments to provide enhanced management guidance and advice in an accessible format via DSTs.
- **Communications:** Rolling out the implementation of the project outcomes, via deliverables targeting the needs of ICES/NSASCO, and communicating with the wider management community, at local, national and Atlantic Basin scales.

### Board Request

The Likely Suspects Framework Workshop in November 2017 was the first scientific event held under the auspices of the International Year of the Salmon. With the endorsement of the Board/NASCO, the LSF was subsequently adopted as an IYS signature project. The subsequent, trans-basin working relationships that have developed between Atlantic salmon researchers and Pacific salmon scientists have formed the basis for a series of on-going scientific initiatives. The LSF project is currently engaged in workshops with Pacific salmon researchers, helping to develop case-use studies, with a view to implementing the LSF approach in the Pacific Basin, and with researchers in eastern Canada, through the multidisciplinary Canadian AJSRV, collaborative science project.

The current proposal reflects what is emerging from these discussions. The close parallels between the challenges in the two basins are now clear to those engaged in such co-operative programmes. What is also clear is the need to develop a suite of dynamic, ecosystem indicators, which align closely with the emerging concept of integrated ecosystem assessment. The aim of this proposal is to build on earlier co-operative successes such as SALSEA and to forge close links with those engaged in current projects such as SeaSalar, SMOLTRACK, the Greenland Tracking Programme, SAMARCH, SeaMonitor, the Moray Firth and Scottish West Coast Tracking Programmes. Many of the principals in these projects are serving on the External Advisory Board of the LSF.

In our view the Board, working through NASCO, is ideally placed to co-ordinate such an internationally focused development. The Board is basin wide in its scope and is ideally placed to encourage Parties to embrace this new paradigm and to become full partners in the programme by aligning their marine salmon programmes under the umbrella of *the International Atlantic Salmon Modelling and Management Initiative*.

Very significant funding, both public and private sector, has been invested in the establishment of the Likely Suspects Framework research team and in the development of the Life Cycle Model to date (*circa* £500k to date). These human and intellectual resources will be fully available to ISMMI.

The chances of success of such a major bid (*circa* £3-5m) would be considerably enhanced by the support of key inter-governmental organisations such as NASCO. The Board's endorsement and matching financial support of £96k is therefore requested for one year to allow our consortium to a.) align existing salmon stock assessment and management models in preparation for the bid, improve engagement with salmon management at all levels and define existing key roadblocks and b.) appoint a suitably-experienced and qualified research proposal developer to build a trans-national research project funding bid (EU-Horizon or similar).

Fundamental to the work of NASCO and ICES are improvements in scientific advice to managers and the integration of advice on salmon populations across their marine phases, with ecosystem data emanating from other relevant ICES programmes. As outlined above, we believe that a future vision for international salmon conservation and management must move beyond the provision of catch advice based on single-species demographics. It must encompass a wider eco-evolutionary vision, which recognises the speed of change in both the ocean and in our climate and which can tackle the

urgent and fast moving challenges facing salmon populations for the remainder of this century. We believe that the Board is best placed to ensure the co-ordination that is required to oversee the evolution of ISMMI and to deliver on the comprehensive, 5 year, strategic plan as outlined in this proposal.

Dr Colin Bull	Missing Salmon Alliance, UK
Dr Walter Crozier	Atlantic Salmon Trust / Missing Salmon Alliance, UK
Professor Ken Whelan	Atlantic Salmon Trust, UK
Dr Etienne Prévost	INRAE (National Research Institute for Agriculture, Food and Environment, France)
Dr Etienne Rivot	Institut Agro, Agrocampus Ouest, France
Dr Matthieu Buoro	INRAE (National Research Institute for Agriculture, Food and Environment, France)