International Atlantic Salmon Research Board

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The AST Likely Suspects Framework: A conceptual framework for evaluating marine mortality in Atlantic salmon

(Tabled by the Atlantic Salmon Trust)

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Background

The Atlantic Salmon Trust has been developing a framework for conceptualising survival issues impacting Atlantic salmon during the freshwater migration phase and subsequent marine phases and to provide coherent guidance on how future research on survival can be identified and prioritised:

- The concept places candidate mortality factors (Likely Suspects) within an overall spatio-temporal framework (the Likely Suspects Framework) covering the freshwater migration and marine phases of the life cycle. Key geographical areas and periods where mortality factors are known or thought to operate are characterised as ecosystem "domains".
- Domains can be identified at various locations, ranging from freshwater to overwintering feeding areas, and will be associated with different mortality factors.

The process of identifying the various domains and matching candidate mortality factors will prompt specific testable hypotheses about the operation of the factors involved and hence aid targeting of research to further refine the estimates of the potential scale of, and variation in, mortality at each part of the freshwater migratory and marine phases:

- The objective over time is to firm up the numbers at the domains and thus further partition and more clearly understand marine mortality beyond what is achievable at present.
- This approach will be of interest to managers and policymakers at various levels, since mortality is a cumulative process, with salmon from each stock experiencing mortality at a series of ecosystem domains on the journey before returning to spawn.

The AST led an International Workshop in November 2017, at which salmon scientists from the Atlantic and Pacific regions investigated how such frameworks could be set up at various spatial scales. Such a collaborative hemispherical approach aligns closely with the objectives of the International Year of the Salmon (IYS) initiative. The LSF is recognised by IYS as a signature project within the IYS planning strategy and the workshop provided the first joint Pacific/Atlantic scientific output from the IYS initiative to date.

- The workshop identified the potential to further extend and develop the Likely Suspects Framework concept by conducting targeted studies of the factors influencing survival of Atlantic at ecosystem domains that the framework identifies.
- The workshop concluded that, via a mix of empirical and modelling studies at key domains, it should be possible to evolve the LSF into an ecosystem modelling approach that would begin to further resolve the mechanistic basis of cause and effect of the main mortality factors (the likely suspects).

- This will help refine the predictive models used by ICES to advise international management at NASCO.
- A further outcome of the workshop was the establishment of an on-line operating framework for Pacific and Atlantic scientists working together (The Likely Suspects Forum on *Salmon Ocean* – part of a Pacific forum designed to foster collaboration and exchange of information to support research bids and funding opportunities).

The ICES Working Group on North Atlantic Salmon recognises the value of developing high-level conceptual frameworks that may lead to hypothesis-led research into sources of and partitioning of marine mortality in Atlantic salmon. WGNAS also notes that ICES encourages the use of their ecosystem databases and products to assist with developing such frameworks and research into the underlying mechanistic relationships between variability in ecosystem drivers at particular domains and trends in salmon mortality.

Refining and developing the Likely Suspects Framework

Further work should be developed in two phases:

- **Phase 1** would revise the framework along the lines suggested in the workshop to confirm the domains of interest and provisionally align candidate mortality factors with each. This leads to the creation of a portfolio of hypotheses about the mechanistic relationships involved at various domains and points to data requirements (and hence gaps). Domains should be representative of all phases of the salmon's life history: freshwater, the transition from freshwater to marine, life in a fully marine environment and the phases associated with adult return to freshwater.

- **Phase 2** would focus initially on one or more ecosystem domains, to test the specific hypotheses associated with survival and to develop (or apply) models and methods to resolve the mechanistic basis of survival variation there. The approach is to start by using what is known, or thought to be the known, about the ecosystem and build up as information on functional relationships becomes available.

Many of the areas discussed in detail at the workshop related to the marine environment, reflecting the perceived lack of data relating to growth and survival of salmon at sea.

Actions specific to the Atlantic Basin

1. **Getting the scientists together**

Workshop Conclusion: Progress on salmon mortality at sea will depend on a multidisciplinary approach and therefore, oceanographers; predator and competitor experts will have to become involved. The workshop suggested that an initial step towards integration would be that ICES WGNAS should request that ICES arrange for an oceanographer to attend their meetings to provide an annual update on oceanic conditions/events.

Comment: WGNAS suggests the other way round might work better; i.e. if WGNAS sends a representative to attend some of the ICES ecosystem/environmental groups.

2. Getting the data together

Workshop Conclusion: For Phase 1 there is a need to compile good documentation on the survival time series of wild Atlantic salmon. The workshop developed an illustrative spreadsheet of the required data attributes at various scales. This should be extended to include other relevant data such as growth (scales), genetic diversity (DNA) and migration history (from otolith trace elements) and should be further developed in joint consideration with other databases.

Comment: There is a need to get together in a workshop format (perhaps under the auspices of ICES) to evaluate/document this. Data will then need to be standardised and made accessible to import into analysis at domain scale. The workshop does not need to be large (8-10 participants), but would require data input from all WGNAS national representatives. A smaller subset group of experts (say 3-4, from US, Canada and, Europe) would then take forward exploratory covariance analysis to identify/confirm the domains and develop the list of hypotheses.

Workshop Conclusion: It is not immediately clear if ICES databases are organised in such a way as to support access both to metadata on ecosystem components and time series data series that can be used during Phase 2 in researching functional links between diverse ecosystem components such as fish, birds and mammals.

Comment: Discussions at ICES WGNAS in 2018 indicate that ICES is keen to make best use of their ecosystem/environmental databases and products, but to move this forward would require a specific commitment from ICES at management level. Note, ICES ecosystem assessments are mainly descriptive and have not evolved towards having predictive capability. This is a feature of some Pacific salmon ecosystem assessments, which try to take a forward look at the "prospects" for salmon survival under various oceanic conditions.

3. Salmon as a pelagic indicator species

Workshop Conclusion: Steps should be taken through ICES, NASCO and the EU to promote the Atlantic salmon as a pelagic species and a key indicator of marine ecosystem health. This form of leverage will be necessary to ensure that appropriate ecosystem surveys are carried out in the N. Atlantic in areas of relevance to salmon and that support is generated for any new targeted "salmon at sea" surveys judged necessary.

Comment: High level scientific and management consensus is needed, together with political support, to promote this. A review should be conducted of the previous and current salmon at sea sampling programmes, in the context of what additional surveys and sampling will be needed, including where existing ecosystem surveys (for example the International Ecosystem Summer Survey of the Nordic Seas, IESSNS) can be extended to include areas of particular relevance to Atlantic salmon.

4. Natural mortality during the second year at sea

Workshop Conclusion: It was agreed that there is scope for a broad comparative analysis of natural mortality "M" during the period following the 1ˢᵗ January of the first winter at sea for a range of stocks across the Atlantic range of salmon. This would examine the variations in natural survival during the second year at sea (i.e. after the decision to mature has been taken). ICES needs to know whether M varies temporally and spatially, especially at the assessment unit level.

Comment: This is a clearly defined and ring fenced study (probably about 4-6 months), largely using existing data sources and of immediate relevance to enhancing ICES stock assessment and catch advice.

5. An *"energetics of the ocean"* approach to researching salmon mortality

Workshop Conclusion: A research theme was proposed to investigate the energetic changes (energy density variation) needed to explain the changes in maturation profiles that we are seeing. A specific example might be researching the partitioning of the energy budget in salmon at sea during critical phases where many stocks coalesce (e.g. W. Greenland).

Comment: This is a novel approach to understanding why more salmon are dying at sea compared to earlier time periods. Two complementary approaches were considered: specifically exploring the potential influence of ocean productivity shifts (energy density changes) on resource allocation strategies and life history traits; and exploring the evolutionary and demographic consequences of such patterns using IBASAM. This would be a two year stand-alone project combining theoretical work on energetic strategies in Atlantic salmon and whether observed changes in energetic content of prey in key oceanic areas could be responsible for the changes in maturation profiles of salmon that are being observed.

6. Survivor bias

Workshop Conclusion: Survivor bias is a problem. We only see the salmon that survive and have also lost sources of data as at sea fisheries for Atlantic salmon decline.

Comment: This justifies a renewed/enhanced "at-sea" sampling program, particularly at West Greenland.

7. Atlantic salmon Bayesian life cycle model development

Workshop Conclusion: The workshop endorsed further development of the Bayesian life cycle model for Atlantic salmon being developed for stock assessment and catch advice at ICES, with an emphasis on partitioning marine mortality along the migration routes at sea.

Comment: ICES WGNAS recently held a workshop to review data inputs and needs in the specific (narrower) context of adopting the model for catch advice by WGNAS, however the further aspects discussed at the LSF workshop go beyond that and have wider research relevance. This merits a stand-alone research project (18 months?), but linked to LSF as the overarching justification.

8. Linking the Likely Suspects Framework with Atlantic salmon models

Workshop Conclusion: A further project would seek to integrate the IBASAM model, or any other theoretical framework approach developed under the *"energetics of the ocean"* approach above with the Bayesian life cycle model as used at WGNAS. For example, IBASAM modelling could be used to set up scenarios that would be tested as prior assumptions in an enhanced Bayesian life cycle model that WGNAS intends to adopt.

Comment: This would be a progressive bringing together of the various stands outlined above within the overarching LSF as the information becomes available to fill in the domains (or in some cases make model based estimates of likely values).

Atlantic and Pacific working together

Workshop Conclusion: Evidence on climate change driven impacts on salmon species at hemispherical scale was identified as a major research gap. Is there a potential hemispherical impact of wider scale climate drivers such as El Niño on salmon species (telekinetic effects)?

The workshop identified two particular research priorities at hemispherical scale:

- One proposal is to assess marine survival/abundance trends across species and oceans for co-variance. This would be a powerful connector and might help to further isolate some of the broader factors at play and functionally how they are leading to changes in salmon productivity.
- A particular research priority would be jointly investigating climate change drivers and impacts on salmon at hemispherical scale.

Comment: These research topics would help identify broader scale factors potentially contributing to changes in salmon productivity and they align well with International Year of the Salmon (IYS) priorities.

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