



**International Atlantic Salmon Research Board**

**SAG(17)4**

*Salmon at Sea: a 'likely suspects' approach to guiding research*

*(Tabled by the Atlantic Salmon Trust)*



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### ***Salmon at Sea: a ‘likely suspects’ approach to guiding research***

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#### **Background**

The EU-funded SALSEA research collaboration led to a step change in the state of knowledge of European Atlantic salmon at sea. In particular, SALSEA established the concept of an annual “conveyer belt” of northward migrating smolts. Along this route, the number of smolts declines due to cumulative effects of natural mortality as well as any fishing mortality. In particular, SALSEA identified the existence of “choke points” in the ocean, where there is coalescence of migrating smolts in relatively restricted geographical areas and where there is believed to be potential for variations in oceanic conditions to alter the destinations of migrating smolts. Additional mortality factors likely operate during the overwinter feeding phase and on return migration to home waters and entry to rivers.

While SALSEA identified potential sources of mortality during the initial smolt migration to feeding grounds, it did not aim to quantify or fully understand these. It is evident however, that since these factors can vary in time and space, such variation may be expected to account for some if not most of the variability in return rates observed among salmon stocks and between years.

As plans for new research develop, it is necessary to consider how that research can be targeted and prioritised. This concept note, prepared by the Atlantic Salmon Trust (AST), suggests that it is possible to identify an overall strategic framework that would provide coherent guidance in this regard.

#### **What is the strategic objective of the proposed new research?**

A strategic approach is proposed that would place candidate mortality factors within an overall spatio/temporal framework of salmon throughout the marine phase, with a view to quantifying the potential of each factor to influence survival (the “likely suspects”) and to link these dynamically in such a way that the cumulative effects of these factors is made to account for the observed survival variations in cohorts of salmon.

Given the number of, and variation in, likely factors influencing mortality at sea, the approach is not designed to be modelling in the meaning of inputting variables to test or predict outcomes, but is more akin to an “accounting exercise” and can be used to identify the likely impact both individually and cumulatively of the “suspects”. A key objective is to 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 mortality at each part of the marine phase. A particular focus would be on identifying where and how

mortality factors had changed between earlier periods of higher marine survival and the more recent/current low survival phase.

### **How will the likely suspects framework be established?**

As a starting point, the approach would be to take known historical data on salmon abundance and survival, including PFA estimates etc from ICES and construct a simple broad-scale model, perhaps at stock complex or country level (for example sNEAC) which begins to quantify and partition the losses of salmon at sea in recent years compared to previous periods of higher survival. This focus on losses/mortality leads to the question....

*“What additional mortality in terms of numbers of salmon is needed to account for the difference and where should this mortality be allocated?”*

Given overall quantitative estimates of the “lost” fish, known or suspected mortality factors would then be introduced as “nodes” in the model and existing knowledge used to provisionally partition the lost numbers into these factors. The mortality levels initially allocated to the various nodes would be subjected to reality check using current knowledge and this can point in the direction of the likely suspects having greatest influence on mortality at sea. For example, if the framework suggests that the number of “lost” fish for a national stock is 300,000/year on average compared to the 1980s, then we can ask questions such as....” *Can predation by seals in coastal waters of that country be considered remotely capable of accounting for this number?”* If the considered opinion is no, then a more feasible allocation can be initially inserted and the number still unaccounted for must then be re-allocated elsewhere in the framework.

This should be done for North American as well as European stock complexes and also for ISW and MSW components, as this will help to identify factors that cannot be common to these stock complexes and also those that might be common. Therefore, some early refinement of the relative importance of various nodes may be possible. For example, pelagic fisheries in the Norwegian Sea can hardly be impacting North American post-smolts in the Labrador Sea, whereas different factors must be impacting stocks that have MSW components occupying common feeding grounds off Greenland.

Since several mortality factors of interest may operate in particular localised areas or on small groups of stocks, it is recognised that populating the proposed mortality nodes at stock complex level may not establish a full picture of the mortality factors at work. However, a key attribute of the likely suspects framework approach is that it can be adapted to various scales. It is therefore proposed that the framework would subsequently evolve to adopt a cohort approach, whereby variation of marine mortality would be considered on individual cohorts and where possible on an individual stock basis on selected stocks from each stock complex. This is required to tease apart variation in mortality between years and between stocks, as mortality still varies spatially and between years even within a period of generally suppressed/depressed survival as encountered in recent years.

The cumulative and synergistic effects of factors such as environmental change and fisheries induced evolution on genetic “fitness” and hence survival at sea cannot be ignored among the likely suspects. For example, delayed maturation inevitably increases cumulative mortality at

sea. At the single stock level an eco-genetic modelling approach could address an evolutionary perspective, drawing on principles of individual based demographic modelling (IBASAM). This would involve introducing a different type of node; a “virtual node” that would incorporate estimates of increased mortality in that stock due to loss of genetic adaptation under rapidly changing environmental conditions. At single stock level, further mortality nodes may be required; for example, it is recognised that specific local mortality factors operate on smolts while they migrate down through freshwater stretches before reaching the marine environment.

It is likely that much of the previous and ongoing research on tracking (and genetic assignment) of post-smolts will be amenable to populating versions of the framework based on individual stocks. Similarly, the ICES “index” or “monitored” rivers, where demographic/biological attributes of individual stocks and where return rates for each sea age component are known, would be ideal candidates to supply data for this aspect of the study.

### **What does adopting this framework imply for future research on salmon at sea?**

The value of the proposed framework is to link together the scale and patterns of mortality at broad regional scale and over decadal time scales, together with the fate of individual cohorts and of individual stocks. Since it is known that various candidate mortality factors drive salmon survival at sea at broad regional/oceanic scales, while others likely operate at more local scales (coasts and estuaries), and that some or all of these factors may vary between years, then the proposed approach offers a coherent adaptive framework within which appropriate research can be identified and prioritised.

The advantage of this approach is that populating and refining the “nodes” of the framework directs research to particular topics. The overarching objective is therefore to progressively firm up the numbers at the “nodes”. This will also have the effect of concentrating research priorities on nodes where unaccounted-for losses appear to be greatest. The interconnectedness of the various nodes also facilitates simple modelling of the potential impact of management measures on factors that can be influenced, e.g. temporarily adjusting timing and location of pelagic fisheries to avoid areas of post-smolt concentration.

Although the initial development of the conceptual framework for this approach is more an accounting exercise than mathematical modelling, it shares many similarities with the operation of Bayesian belief networks. In these networks nodes are also used, each having a set of possible values or states and between which links represent relationships between the nodes. The assumed probabilities of certain events or outcomes at each node are referred to as “beliefs” and these are refined/updated as evidence accumulates from research. Although the picture of salmon at sea will involve numerous mortality nodes, smaller groups of nodes may be amenable to the Bayesian belief network approach, particularly in the single stock examples.

Perhaps the biggest research challenge will be investigating links between oceanic environmental/ecological conditions and post-smolt and adult survival. Although evidence exists of links between conditions at sea and salmon growth and body condition, the direct functional links between any factor, or group of factors, and salmon survival are not well understood. However, given sufficient observational information, it may be possible to

develop a better understanding of how annual variation in these factors may correlate with mortality variations in individual monitored stocks, and by inference of wider stock groupings. In terms of populating the nodes of the proposed framework, it may initially be sufficient to use proxy measurements that are statistically linked to the actual mortality factor(s). For example, wind/current forcing in a particular year may set post-smolts on a migration path that subsequently results in higher mortality, so it is important to know this and account for it in the framework. This approach was previously adopted in the development of the SALSEA Merge migration and distribution model.

Policy drivers increasingly require the adoption of an ecosystem approach to marine fishery management and this means that surveys at sea are increasingly developing into multi-disciplinary, ecosystem surveys. This approach will over time increase the data available on wider ecosystem components beyond the fisheries stocks being assessed. The International Ecosystem Survey of the Nordic Seas is a particular example relevant to Atlantic salmon, but does not cover all areas of interest.

Data on temporal and spatial variations in oceanic environmental/ecological conditions affecting salmon at sea will be important and this implies that a routine “at-sea” core-monitoring programme is established that would target areas of particular importance for Atlantic salmon. There is an opportunity to present the Atlantic salmon as an important pelagic species and to acknowledge it as a key indicator of marine ecosystem state.

There is therefore much scope for closer collaboration between oceanographers, ecosystem modellers and salmon scientists. The AST Likely Suspects Framework could provide a clear strategic focus for supporting such developments.

### **How does this proposal relate to ongoing or proposed research elsewhere?**

Exploratory discussions with scientists in this field have indicated that the proposed conceptual framework would fit well with ongoing and new work in several areas. For example:

- Significant research is ongoing to model the interactive effects of selective fishing and environmental change on Atlantic salmon demogenetics. This individual based demogenetic modelling is well placed to incorporate an evolutionary perspective to help populate the virtual nodes at single stock level of the likely suspects approach.
- New work on embedding stock assessment within an integrated hierarchical Bayesian life cycle modeling framework in the N Atlantic is aimed at improving PFA forecasting by ICES and hence catch advice to NASCO. Scientists leading this area have indicated that this Bayesian model would provide a good framework to test the impact of various likely suspects individually or in combination.
- Department of Fisheries and Oceans, Canada has established an Atlantic Salmon Joint Research Venture, and some of the work funded under this initiative has direct read-across to the likely suspects approach. For example, Dalhousie University is developing a stochastic salmon life history modelling approach, to further investigate mortality and its causes. Part of this work aims to identify life history stages that have the greatest influence on survival parameters and aims to identify testable hypotheses

for the most probable mechanisms affecting salmon viability at different spatial /population scales.

The likely suspects approach would therefore provide an overarching template that can subsequently be populated with emerging data from these and other projects. The establishment of a conceptual framework would also support consortium groups in targeting bids for research on salmon at sea as it will help avoid overlap/duplication and will help funders target resources at the most important nodes in the marine phase of the life cycle. Through updates it will also indicate the state of progress in research on mortality at sea.

As an example, the proposed framework would provide a valuable new perspective on the research activities listed in the IASRB *Inventory of Research Relating to Salmon Mortality in the Sea*, as it would allow “mapping” showing the degree of alignment of these activities to the various mortality nodes identified in the framework. Similarly, such a framework is also relevant to the developing research priorities of individual organisations. For example, it provides clear linkage between many of the components within the “Ocean” and “Inshore and Coastal” key pillars of the *AST 10 Year Science Strategy*.

A further benefit envisaged for the likely suspects concept, is that the framework being developed would be a valuable tool to help managers and stakeholders visualise and understand the impact of the various mortality factors impacting salmon stocks at sea. A web based tool could be developed that would present users with a map based version of the marine phase of the life cycle and allow users to vary the impact of changing the various mortality factors within ranges to be established during development of the framework. Users could visualise the challenges faced in assessing salmon mortality at sea and understand why research was being targeted in certain areas. This ‘tool’ would integrate well with the web based Salmon Population Modeller being developed by the AST and the Institute of Fisheries Management (IFM).

### **Management applications**

Apart from providing a strategic framework to identify future research priorities, the likely suspects approach may, in time, have direct application to helping the development of models required for management advice, such as predictive modelling of pre fishery abundance (PFA) as required by ICES.

For example, the new state-space Bayesian modelling approach being developed to facilitate ICES advice to NASCO is aimed at forecasting trends in Pre Fishery Abundance (PFA). The model generates post-smolt survival rates and the proportion maturing as 1SW fish; these forming the basis for forecasting homewater returns under various catch options in the mixed stock sea fisheries. At a minimum, this developing ICES model could be used to examine what-if scenarios quantifying the effects of the likely suspects mortality factors individually or synergistically. It may also be possible that the PFA forecast capability for ICES can be developed in a direction where the likely suspects mortality factors are used to fine-tune the two key forecasted trends?

## **Project implementation**

Although costs to fund the development and operation of the proposed likely suspects approach have not yet been estimated, these would be small in comparison to the costs of the actual “at sea” research. It is likely that a relatively small core scientific group from Europe and North America could pursue this work over a 2 year period, via an EU Concerted Action or similar. The crossover of the proposed framework to North American salmon stocks may offer opportunities to seek funding contributions from interested parties in both Europe and North America.