International Atlantic Salmon Research Board *Projects of Interest to the Board and its Work*	**ICR(22)07** **Agenda item: 5**

Projects of Interest to the Board and its Work

Purpose

The purpose of this paper is to provide an update on projects of interest to the Board and its work, namely the SMOLTrack projects and the Likely Suspects Framework.

Decisions

No decisions are required.

Background

At the 2020 Annual Meeting of the International Atlantic Salmon Research Board (the Board), ICR(20)16, it was agreed that an Agenda item would be retained in future years which focused on projects of interest to the Board and its work. This would include information on projects where NASCO has some ownership (such as EU-funded projects, the SALSEA-Track successor, when agreed, and the Likely Suspects Framework) and other relevant projects; those researchers could be invited to contribute information, CNL(20)12. The Board asked the Secretary to provide updates on projects where NASCO has some ownership and, through the Board and SAG members, to seek information on new and emerging projects that would be of interest to the Board and its work.

Prior to the 2022 Annual Meeting of the Board, the Secretariat asked Board members and SAG members to provide information on any new and emerging projects that they were aware of, that would be of interest to the Board and its work. No details of projects that fall within the scope of the Board's activities, or that are not already listed in the Board's Research Inventory, were provided.

The leaders of the SMOLTrack projects and the Likely Suspects Framework have provided an update on their work, as follows.

SMOLTRACK PROJECTS

The EU has provided funding to NASCO to support the following SMOLTrack projects:

- Understanding and comparing early mortality of European salmon populations at sea (SMOLTrack I – completed);

- Comparing mortality of European salmon populations at sea using multiple -method telemetry studies (SMOLTrack II – completed);

- Quantifying smolt survival from source to sea: informing management to optimise returns (SMOLTrack III – ongoing. Update below); and

- Quantifying salmon survival from river exit to return as adult: Collecting thermal and behavioural data to refine smolt to adult survival indices (SMOLTrack IV – ongoing. Update below).

The website for the projects is: SMOLTRACK. There is also information on the Board website.

SMOLTrack III: Quantifying smolt survival from source to sea: informing management to optimise returns

Summary of the Action

Recent marine survival estimates are amongst the lowest recorded in decades and indicate that as little as 3% of wild smolts now survive to return as adults. In recent decades, survival at sea has generally been accepted as the key determinant of river stock abundance. However, recent research conducted in Denmark, England, Ireland, Spain, Sweden and Northern Ireland through the EC-funded SMOLTrack and related initiatives have indicated that smolt mortalities during the early outward migratory phase from 'source to sea' may be much greater than previously assumed. In addition, various studies have demonstrated that a reduction in negative pressures (e.g. predation, aquaculture) on smolts in this zone of influence can ultimately boost associated adult returns. Therefore, it has become apparent that significant knowledge gaps remain to comprehensively understand, quantify and partition the principal cumulative factors responsible for Atlantic salmon smolt survival during this critical life stage.

Successful outward migration is likely influenced by a variety of factors such as smolt size condition and physiological status, habitat structure, predation pressure, sea lice-induced mortality from salmon aquaculture (if present) and the effects of regional and local climatic conditions including flow and temperature regimes. The proposed project aims to identify and evaluate the relative contribution of several of the principal factors responsible for early smolt and post-smolt mortality in order to better inform the development of fisheries management strategies that may optimise natural smolt production and consequently enhance the probability of wild adult returns. The project will evaluate potential pressures on migrating smolts identified from several previous SMOLTrack work packages, including predator bottlenecks and thermal stressors. As migration survival is best assessed via telemetric studies, an additional central focus of this project is to validate the effect of tagging on fish behaviour in order to better ensure the accuracy of such assessments. In the freshwater, transitional and coastal zones, fisheries managers have much greater scope to implement successful measures to reduce pressures on out-migrating salmon compared to the vast oceanic environment, where the stock protection measures are principally limited to regulating commercial fisheries.

To address these issues, the following work packages (WP) comprise the project:

- WP1 Eval-smolt

- WP2 Thermo-smolt

- WP3 Hand-smolt

The following EU jurisdictions participate in the project: Denmark; Finland (new partner); England; Ireland; Northern Ireland; Portugal (new partner); Spain and Sweden.

The leader of the SMOLTrack Project, Professor Kim Aarestrup, DTU Aqua, provided the following update in April 2022.

Progress on SMOLTrack III

Most of the planned smolt tagging was carried out in 2021, despite the continuing Covid-19 problems.

Work Package 1: Eval-smolt

Description: wild smolt to adult survival will be assessed using two tagged groups (treatment and control). Both groups will be intercepted in freshwater and tagged with transmitters and Passive Integrated Transponder (PIT) tags during their outward migration. The control group will be released in freshwater at the tagging site. The treatment group will be transported downstream and released to avoid existing identified smolt-loss bottlenecks. Survival will be measured during migration via the transmitters and in adult returns to trap (via PIT tags).

In each project site, smolt survival with and without smolt bottlenecks will be established, testing the potential effect of the bottlenecks and lead to a predictive model showing the potential benefit of management actions towards removing or limiting bottleneck effects.

Update: studies were continued on the Eriff, Bush and Lima in 2021, after most were postponed due to Covid-19 in 2020. On the Eriff and Bush, the aim is to look at moving fish past the identified bottlenecks. On the Eriff, there was low survival in both groups. Potentially, the low survival is due to an unusual year and the study will be continued in 2022, with an increased focus on other potential causes of smolt loss especially in relation to capture, handling and tagging-related stress in combination with the presence of predators. On the Bush, tagged smolts released downstream of the bottleneck survived significantly better. This study will also be repeated in 2022. We anticipate the results from the two rivers will be ready for publication after another year of data and will fit very well into the project of our newly recruited PhD student. A camera study was performed in the Bush in spring 2021 (postponed from 2020).

Work Package 2: Thermo-smolt

Description: this WP aims to build upon the extensive latitudinal distribution of the partners to monitor the relationship between smolt run and related temperatures in the river and receiving sea waters. Associated temperature and hydraulic data will be collected and compiled from stations throughout the project study areas. These data will be matched to the smolt run in the selected rivers to understand if there is geographic variability in conditions which salmon smolts encounter. For each catchment in WP1 and WP2 the main natural and anthropogenic pressures will be identified so that the effects of streamflow and temperature can be isolated.

In addition, an applied study is planned to monitor the behaviour of a group of hatchery-reared smolts held at an elevated temperature (+ 5°C) for a month immediately prior to their migration into coastal waters and compare to that of an untreated group. Age and growth of smolts in all systems will be determined from scale samples.

Both studies will inform of potential thermal stress and the adaptability of the species at this vulnerable life stage under various temperature / climate scenarios.

Update: the run timing and temperature data collection continues among partners. In the Lima, smolt trapping was performed in 2021 to evaluate the timing of smolt migration and collect biometric data from migrating smolts via trapping. As the southernmost river basin in Europe with known salmon reproduction, the Lima may provide useful information on timing of smolt migration at this extreme location that can be compared across a latitudinal gradient of variation. Unfortunately, 2021 was a very bad smolt migration year in Portugal and only three salmon smolt were caught. The study will continue in 2022, but trapping will be moved to a tributary of the River Minho.

Work Package 3: Hand-smolt

Description: fish telemetry studies are based on the assumption that a tagged fish's behaviour is representative of untagged conspecifics. In the context of SMOLTrack and any similar study this assumption implies that the risk of predation for tagged fish is equal to that of the control. This WP will undertake a strategically important research study aimed at testing this assumption in the field. Published and unpublished evidence is available showing that the influence of tagging on predation risk is minimal, but a detailed study is required for the specific situation with migrating smolts to validate results for management and to address potential peer-review concerns (all countries) and advice for future study setup. We will compare the survival between groups of smolts, tagged with different methods, and evaluate their performance against control groups.

The research in the three WPs will apply various methods on wild salmon smolts to broaden

the understanding of indirect and direct causes for mortality in the transition from freshwater to the marine environment over the entire geographic distribution of salmon in NE Europe. In WP1, smolts will be caught, tagged with PIT, radio- or acoustic tags in rivers from Spain to Finland, and their fate after release determined.

The results from WP1 combined with downstream trap catch data will be used in WP2 to infer the temperature and flow conditions experienced by the various populations in order to understand and predict optimal thermal conditions for salmon smolt migration. The results will be matched to data from WP3 to understand potential uncertainties that may be associated with smolt predation studies which are based on results from tagged fish.

The new project will take advantage of, and expand, an existing platform within the SMOLTrack partnership of EU-wide salmonid telemetry knowledge. This, together with availability of existing partner datasets, extensive experience of migratory fish project delivery and the advantages arising from bulk purchasers of tagging technology, will ultimately facilitate the sharing of international best practices to EU members.

Update: DTU carried out a pilot study in 2020 comparing the survival between a group of smolts electro fished and tagged before the migration period with that of a similar group tagged in a trap. The study will continue in 2022 along with a similar study in the Ballycastle River in Northern Ireland.
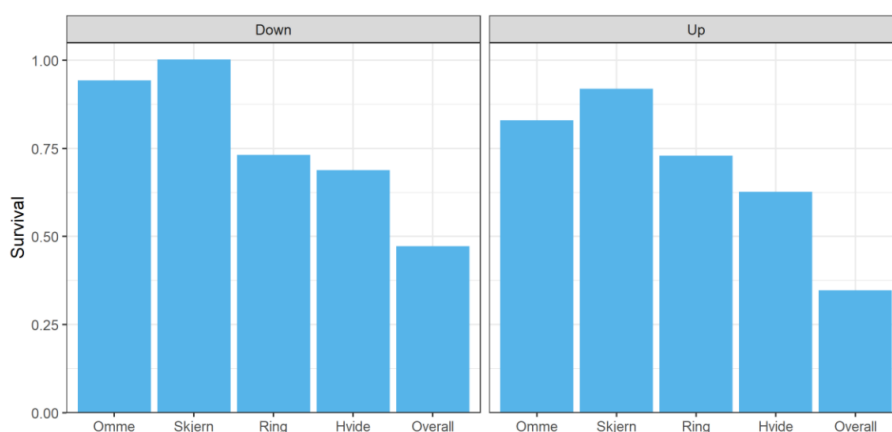
Results from the first Hand-smolt study in Omme / Skjernå 2020. The two groups of tagged smolt showed similar survival from Skjern Å to outside Ringkøbing Fjord.

SMOLTrack III Outputs

Results are still being collected and processed. The results from the Danish kelt study are almost ready for submission. The overall smolt survival paper was submitted and is now in review.

SMOLTrack IV: Quantifying salmon survival from river exit to return as adult: Collecting thermal and behavioural data to refine smolt to adult survival indices

Summary of the action

Recent marine survival estimates are amongst the lowest recorded in decades and indicate that as little as 3% of wild smolts now survive to return as adults. In recent decades, survival at sea has generally been accepted as the key determinant of river stock abundance. However, recent research conducted in Denmark, England, Ireland, Spain, Sweden and Northern Ireland through the EC-funded SMOLTrack and related initiatives, have indicated that smolt mortality during the early outward migratory phase from 'source to sea' is greater than previously assumed. In

addition, various studies have demonstrated that a reduction in negative pressures (e.g. predation, aquaculture) on smolts in this zone of influence can ultimately boost associated number of adult returns. Therefore, it has become apparent that significant knowledge gaps remain to comprehensively understand, quantify and partition the principal cumulative factors responsible for Atlantic salmon smolt survival during this critical life stage. However, there is obviously a large mortality in the oceanic phase of Atlantic salmon. The studies into causes and consequences have primarily been done by modelling because detailed information about salmon behaviour and migration routes in the Ocean is scarce. Classic expeditions by ship are prohibitively expensive and furthermore restricted both in time and space and are also to some extent catch-per-unit effort limited. Telemetry has proven to be the only viable method to get detailed knowledge of this behaviour. In recent years a few studies using satellite tags have been published, giving information on salmon migration at sea. Unfortunately, the current PSAT tags are too large to deploy on smaller fish (i.e. smolts), hence the preferred animals to tag are large kelts and the PSATs are typically limited to a 12-month deployment. Hence, there is still a lack of behavioural data, especially for the smaller life stages, and there is a limitation in data describing the return migration from the feeding grounds in the Northern Atlantic.

Acquiring detailed information from salmon behaviour at sea is a challenge and will require a multifaceted approach. The proposed project aims to investigate the post-smolt behaviour during migration from coastal areas to the feeding grounds in the north Atlantic. Additionally, the project aims to identify and evaluate the potential for 'fit for purpose tagging' (FFPT) in the North Atlantic, using insight gained from pilot studies undertaken in previous SMOLTrack projects. Identifying ways to obtain detailed knowledge on coastal and ocean behaviour and migration will be a pre-requisite for a greater understanding of the factors governing behaviour and ocean survival for Atlantic salmon and can feed directly into fisheries management strategies that may optimise and naturally enhance the probability of wild adult returns.

To address these issues, the following work packages (WP) will comprise the project:

- WP1 OceanTemp-smolt

- WP2 FFPT-adult

The following EU jurisdictions participate in the project: Denmark; Finland; Ireland; Portugal; Spain and Sweden.

The following areas outside the EU also participate in the project: England and Northern Ireland.

The leader of the SMOLTrack Project, Professor Kim Aarestrup, DTU Aqua, provided the following update in April 2022.

Progress on SMOLTrack IV

WP1: Temperature experience of post-smolt migrating towards and returning from their ocean feeding grounds.

Description: this WP aims to record the range of temperatures that migrating salmon from smolt stage to adult river return experience over their full oceanic migration. It is recognised that marine temperatures are likely to influence survival and behaviours of smolts at sea. Yet data on the thermal environment experienced by migrants, initially in freshwater, and subsequently in transitional and marine waters are limited. Few data are available due to the small size of salmon smolt which cannot accommodate internal implantation of temperature-logger tags which typically exceed the tag burden smolts can tolerate. Recent advances in logger technology have resulted in increased miniaturisation and this presents a unique opportunity for SMOLTrack IV to collect a key dataset (thermal data for migrating salmon smolt). The project proposes to tag outgoing smolts with miniature Data Storage Tags (DST)

at several river sites across the latitudinal extent of the partnership. This newly developed tag will be implanted in suitably sized smolts on several rivers with a view to capturing freshwater, transitional waters and marine temperature data. With a maximum battery life of 14 months, when logging at 10 min intervals, it is likely that a full return cycle, from smolt to returning adult grilse, will be captured. DST tags must be recovered in order to download the data. This means that this study can only be carried out in systems with a full trap or where removal of the tagged fish is assured. Smolts will also be implanted with a PIT tag to trigger a DST tagged fish recovery at the trap site. With maximum survival rates of circa 5% at least 100 smolts per system will have to be tagged in order to provide a reasonable chance of recovering data.

Recovery of returning adults also presents opportunities to undertake some detailed additional studies, albeit on a small scale, as returns are likely to be low. Nonetheless, various tissues can be recovered and this presents opportunities to understand / map and validate life history aspects. For example, scales will allow for analysis of growth rates versus temperature at different life stages. Refining of salmon scale interpretation by associating it with temperature data may provide scope for validation. Variations in otolith elemental composition are used to reconstruct fish movements. Elemental 'tags' (i.e. otolith stable isotope analysis) may offer scope to assign salmon to specific oceanic areas as defined by isotopic gradients (isoscapes). Combining temperature with otolith chemistry data may offer scope to identify putative feeding residency locations and potentially to suggest potential migration pathways. While it is outside the scope of the present project, the partners will sample the necessary tissues from returning fish enabling the analysis to be performed at a later stage.

Update: in both River Erriff and River Bush, 100 smolts were tagged with temperature Data Storage Tags and PIT tags. The first fish are expected to return in the summer of 2022 and both rivers have enabled increased trap surveillance to collect returning tagged salmon. The tagging continues in 2022. As soon as the first tags are recovered, the data sets will be analysed and by then we will know much more about what to expect from the combined results from both years of tagging. The full dataset will be available by 2024.

WP2. The movement and thermal pathways of adult immature salmon at the feeding grounds and when returning to their natal rivers

Description: in this new SMOLTrack activity, we will go beyond smolts and try to gain information from larger, immature salmon caught at sea at the feeding areas. From earlier studies, we have some information about the migration of MSW / repeat spawners from the home river out to the feeding grounds. This was obtained by using Pop-up-satellite tags on salmon kelts from rivers across Europe. The method is limited in both time of deployment (max 12 months) and the necessary size of the fish (70+ cm). We need, however, data from smaller salmon moving from their natal river to the feeding areas and also from all salmon during their return journey. By intercepting foraging young salmon at sea and tagging these with electronic tags, it may be possible to gain useful insight into this stage of the salmon life cycle.

We wish to extend previous feasibility studies, testing the possibilities of catching salmon at sea, close to Greenland's East Coast and use these for studies of return migration. In the study, there are two stages; a) explore the possibilities of catching reasonable numbers of salmon in an unharmed condition in the Tassilaaq area of East Greenland and by genetic testing to establish the areas of origin of the salmon caught. b) tag salmon with either: 1. long life acoustic tags to record at sea / fjord / river hydrophones upon return; 2. to tag salmon with floating Archival tags (DST) to get information about migration behaviour and route on the return journey; or 3. to tag salmon with PSAT tags to get a clear image of their return migration path. Tagging will also be prioritised on salmon assigned to potential rivers / regions where the SMOLTrack partners are active, to optimise awareness.

Update: the previously postponed pilot study in eastern Greenland was undertaken in

September 2021. The project tested various possibilities of catching adult salmon in the area with the intention to gather information on their return migration. Use of long-lines was difficult and time consuming and failed to catch salmon. Setting of short gill-nets perpendicular from the coast consistently produced catches of salmon confirming high abundance of salmon in the area. Due to logistic reasons, trolling could only be tested during the last 3 days of the trip. After some adjusting of technique, two salmon were finally caught on lures with just a few hours of fishing. The fish were in great condition and were anaesthetized and tagged with floating DST-tags and released on site. In total, samples (tissue, stomach content and scales) from 40 salmon were collected. Salmon origin is currently being determined by genetic assignment. The results are promising for using this method to gain suitable salmon for tagging, similar to the tagging project in west Greenland.

Picture: First salmon caught, tagged and released in Eastern Greenland by SM-IV project.

LIKELY SUSPECTS FRAMEWORK PROGRAMME

The following information was provided by Colin Bull who is the Principal Investigator on the Likely Suspects Framework Programme

Background

At its 16th Annual Meeting (2017) the Board agreed to part-fund a workshop on the Likely Suspects Framework (LSF) concept, which had been developed by the Atlantic Salmon Trust (AST). The workshop, which further refined and developed the LSF concept, was held in Edinburgh in November 2017 and the proceedings were published in the AST Blue Book series.

In March 2018 Dr Walter Crozier attended a meeting of the ICES Working Group on North Atlantic Salmon and sought their support in principle for the LSF approach. Having received this support a full report on the project was provided to the Board at the 35th Annual Meeting of NASCO (2018). The meeting endorsed the LSF concept and agreed to request the Secretary to explore with ICES how best to integrate Atlantic salmon marine survival and population data with relevant ICES marine databases and to suggest that, as an initiative within the International Year of the Salmon, a number of joint workshops might be convened. This suggestion was subsequently agreed and the first of these workshops (WKSalmon) was held in June 2019 with the second scheduled for 2022.

The Likely Suspects Framework (LSF) is the flagship project of the Missing Salmon Alliance[1] (MSA). For salmon managers to adopt an adaptive management approach and to make evidence-based decisions, a detailed understanding is required of the mechanisms driving variation in salmon stock abundance. The LSF programme will assist by:

- providing vital new knowledge on the drivers of salmon mortality from across the life-cycle.

- generating new stock forecasting and scenario-testing capacities to support salmon managers' appraisal of options, and guide their activities

In 2020 and 2021 reports were delivered to the Board outlining project progress. The current report provides an update on project progress over the past 12 months.

Progress in 2021

1. **Developing the core team** remained a key focus of work in 2021. The core team of Principal Investigator (Colin Bull) and Database specialist (Graeme Diack) were joined in 2021 by a contract Ecological Modeller (Neil Banas), a post-doctoral researcher (Emma Tyldesley) and a PhD student (Aislinn Borland).

2. **Supporting co-operative research and the ecosystems-based approach for Atlantic salmon**, the LSF team have focused efforts on developing a shared Database: the MSA's Central Data Resource became live online in July 2021. This online portal provides a unique platform for knowledge exchange and supporting co-operative research on Atlantic salmon. In conjunction with mobilising data resources, the team have carried out an initial expert assessment and prioritisation of a sub-set of mortality hypotheses, and an assessment of regional ocean model hindcasts in support of the NASCO-ICES WKSalmon workshop series.

3. **Development of an underlying mortality framework** as a stage-state model began in 2021, and is at an advanced stage. This will represent the generalised relationship between environmental and biological controls over individual salmon growth and survival in each of the main life stages. It will underpin the ongoing work on developing management decision support tools.

4. **Building decision support tools for salmon managers** was advanced in 2021 by 1. Convening a one day workshop with salmon managers from the UK to discuss knowledge gaps, provision of data and gather their input regarding a suitable pathway for development of a decision support tools to assist their work. 2. Beginning work on the underlying morality framework (above) and 3. Beginning technical options appraisal of a prototype decision support tool to guide development of tools that enable scenario-testing of stage-specific and cumulative effects on survival resulting from particular interventions.

5. **Researching the drivers of salmon mortality at sea** was advanced in 2021 by the commencement of new co-operative research project that examines the drivers of salmon

---

[1] The Missing Salmon Alliance (MSA) brings together leading salmon conservation organisations across the UK -the Atlantic Salmon Trust, Game & Wildlife Conservation Trust, Fisheries Management Scotland, The Rivers Trust and the Angling Trust. It aims to reverse the devastating collapse in wild salmon populations around the UK. By combining expertise, coordinating activities and advocating effective management solutions MSA is focused on ensuring that wild Atlantic salmon populations survive and thrive in rivers, lochs and seas for the next generation.

mortality during the first few months at sea, with a focus on marine prey fields and on building a suite of ecosystem indicators.

6. **Developing science outputs that contribute to the evidence base** and build external collaboration opportunities remain a high priority to assist with the future delivery of this ambitious programme. To this end, significant progress has been made with a number of primary science papers:

    In press: The Likely Suspects Framework: the need for a life cycle approach for managing Atlantic salmon (*Salmo salar*) stocks across multiple scales. C.D. Bull, S.D. Gregory, E. Rivot, T.F. Sheehan, D. Ensing, G. Woodward & W. Crozier. *ICES Journal of Marne Science.*

    *Submitted***:** Enhancing data mobilisation through a centralised data repository for Atlantic salmon (*Salmo salar* L.): providing the resources to promote an ecosystem-based management framework. G. Diack, G., C.D. Bull, S.A. Akenhead, T. van der Stap, B. Johnson, E. Rivot, R. Patin, P.Y.Hernvanne, A. Schubert, T. Bird, M. Saunders & W. Crozier.

    In preparation: E. Tyldesley, N.Banas, C.D. Bull. Disentangling how the ecosystem signals across trophic levels and scales contribute to variation in the survival of Atlantic salmon from Southern European stocks

7. **Agreeing the way ahead for the LSF programme** was undertaken in 2021 as a [five year strategy document] that identified and described five priority work packages (Table 1) matched to available resources to progress four key areas: the provision of resources for research (WP1) , developing new management support tools (WP2,WP3) and catalysing new research into conditions that lead to salmon mortality (WP4, WP5). Figure 1 provides an overview of how these work packages feed into the delivery of the LSF programme aims. Work on many of these work areas is already underway, and formalising the timing and extent of a delivery plan will assist with future resource allocation.

Table 1. Work packages within the Missing Salmon Alliance Likely Suspects Framework five-year work programme

Work package	Brief description
WP1: Continued development of the salmon data library to underpin the LSF process	This will build and develop a fully accessible Atlantic salmon knowledge hub. This will hold the data resources needed for LSF development and in time will support regional and catchment–level salmon management.
WP2: Building the suspects framework	This will use the knowledge from WP1 and other LSF work packages to statistically describe our understanding of salmon mortality processes across the salmon life-cycle. It will provide support for future management activities, in the first instance using available information from ICES Index rivers.
WP3: Building support tools for salmon managers	A prototype decision support tool was developed in 2020 and populated with indicative salmon survival rates. The prototype will be further developed to deliver an online interface providing new decision-support and guidance of relevance at the regional and river-specific scales.

WP4: Populating the suspects framework: priority domains	This implementation study will examine the conditions that lead to salmon mortality during the early marine migration phase using time series data from six salmon Index rivers and newly derived knowledge of key ecosystem components. It will combine information from freshwater and the early marine migration to test two priority LSF priority mortality hypotheses (latent mortality effects from freshwater phase; mismatch with coastal seas productivity).
WP5: Populating the suspects framework: integrating across the life-cycle	This will capture new and emerging knowledge on the conditions that lead to salmon mortality in areas of the life-cycle not yet focused on within the LSF process. This will improve the models to provide a more detailed full life-cycle representation, benefitting management support outputs (WP3).
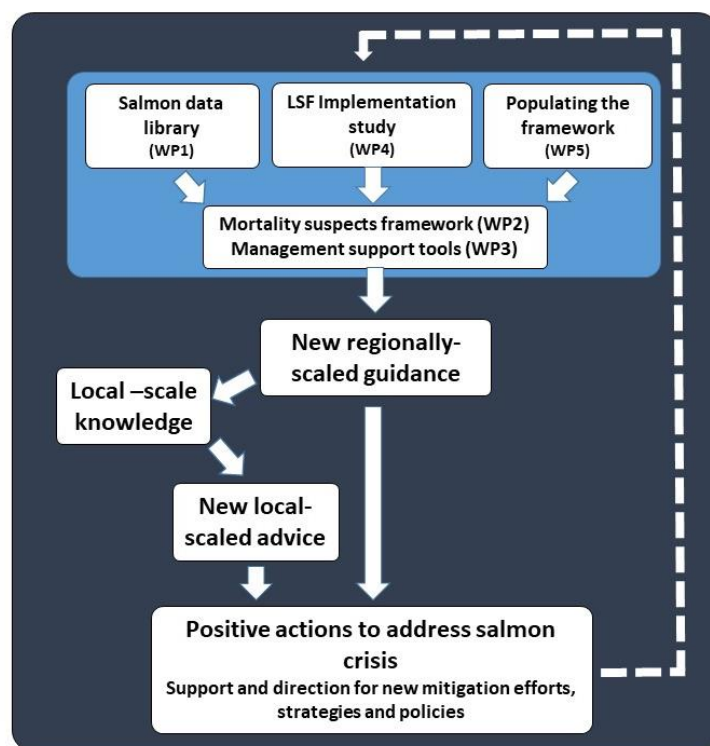
Figure 1. How the proposed strategic components of the programme feed into development of positive actions for Atlantic salmon through generation of guidance and advice

Secretariat
Edinburgh
13 May 2022