International Atlantic Salmon Research Board

ICR(20)05

Progress Report on SALSEA–Track

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Background

At its 2013 meeting, the International Atlantic Salmon Research Board (the Board) agreed that a particular focus of its work should be studies to partition mortality of salmon among the phases of its marine migration. In 2014, the Board adopted a Resolution on Research on Salmon at Sea, ICR(14)6, which, among other things:

- encourages NASCO Parties to continue the development of local collaborative telemetry projects;
- encourages the development of large international collaborative telemetry projects that together build upon and expand local efforts; and
- requests NASCO Parties to make efforts to identify funding sources to support telemetry projects.

To support an integrated collaborative telemetry programme, the Board organised a Telemetry Workshop in December 2014. At this Workshop, twelve outline project proposals for telemetry-based research were developed. In 2015, the Board recognised the high value of the SALSEA brand and the strong impact of NASCO as the international forum for consultation and co-operation on wild Atlantic salmon. The Board had reaffirmed its commitment to an international telemetry project under the SALSEA brand, named SALSEA–Track. Specifically, in 2015 the Board agreed that it would support SALSEA–Track as a continuing commitment to understanding the factors affecting mortality of salmon at sea, to make funds available to prepare a vision statement for SALSEA–Track and to advance existing initiatives towards an integrated collaborative telemetry programme.

The Board recognised that if the international telemetry programme was to proceed, it would be important to follow progress in taking forward the twelve outline projects and, where appropriate, provide support to assist with their implementation.

Between 2017 - 2019 funding was made available through the European Union to support three projects relating to marine mortality.

In February 2020 a review of the SALSEA–Track programme was held. The report of the Working Group will be considered by the Board at the 2020 Annual Meeting.

This paper provides an update on:

A. The twelve outline SALSEA–Track projects;

B. Projects supported by EU funding to the Board; and

C. New telemetry projects reported through the Inventory of Research relating to salmon mortality at sea.

A. Progress on the twelve outline SALSEA-Track Projects

1. Drifters and BioProbes: Options for detecting acoustically tagged fish in large geographic areas (NAC and/or NEAC)

Project description: Line arrays for detecting the movement of acoustically tagged animals and to estimate survival rates have been used in many locations with relatively narrow passage points and in locations in which the movement of animals is assumed to be generally unidirectional. Using line arrays in areas in which animals can disperse over much broader areas is a challenge because of the narrow spatial coverage afforded by these arrays and the short time period which acoustically tagged animals may be in the vicinity of any of the receivers in the array. The use of bioprobes or drifter arrays may be informative in these areas.

Update on Progress (John Kocik and Fred Whoriskey): Funded by the Canadian Atlantic Salmon Research Joint Venture, MetOcean SVP Lagrangian current-following surface drifter buoys have been developed. Annually, hundreds of surface drifters are deployed worldwide by national authorities in support of the World Meteorological Organization's efforts to better predict global weather patterns. This technological development provides an option to national authorities to upgrade their drifters when they purchase them to include acoustic tracking capabilities. These buoys have the potential to be deployed in ocean regions where moored acoustic arrays are lacking or are not feasible due to logistical (e.g. depth) or other (e.g. trawling) constraints, increasing receiver coverage in support of planned animal telemetry studies. A proof-of-concept field test in the Labrador Sea was conducted in 2019 with the deployment of the first acoustic receiver-equipped surface drifter. The buoy was launched in the Labrador Current off the coast of Nunatsiavut in association with the government of Nunatsiavut and Oceans North, and successfully operated for a month before being caught in a current eddy and beaching.

Prognosis and future developments: This tool now offers opportunities to affordably expand acoustic receiver coverage in support of at-sea tracking of Atlantic salmon. Presently, a multi-partner application led by DFO (M. Robertson) successfully passed through the Letter of Intent phase and a full proposal is being submitted to the Environmental Studies Research Fund to track Atlantic salmon through areas off Canada's east coast where offshore oil and gas production / exploration is occurring. This application if successful will include the use of the surface drifters to track smolts and to monitor environmental conditions. The technology is available for use in other studies. Co-ordinated discussions with national authorities responsible for annual purchases of surface drifters and those who are interested in the tracking capability would be useful. Applicability may be informed by modelling efforts described in SRBTW(14)4 (New Receiver Lines/Arrays/Grids (North American Commission area)).

2. New Receiver Lines/Arrays/Grids (NAC)

Project description: Additional receiver detection points would greatly advance our understanding of the marine phase of Atlantic salmon. Additional receiver arrays at key location would provide more robust stock-specific estimates of mortality, migration routes and dynamics during the first year at sea. A number of different potential receiver arrays have been suggested, each addressing a specific aim and information need, but other locations could also be considered.

Update on Progress (Tim Sheehan, John Kocik, and Jon Carr): New receiver lines were added in the Northwest Atlantic in 2018. ASF and DFO initiated a receiver array along the coast of Labrador (i.e. Port Hope Simpson Line) in 2017. The array was doubled in 2018, covering a distance of 32 km from shore. Detections of Canadian and USA origin post-smolts have been identified on the Port Hope Simpson Line each year.

A proposal is working its way through the Atlantic Fisheries Fund (Ocean Tracking Network-Dalhousie University) to provide an acoustic receiver line across the mouth of the Bay of Fundy (southwestern Nova Scotia to south-eastern New Brunswick) in support of tracking projects

that are investigating the ecology and survival of inner and outer Bay of Fundy salmon, and the interactions of wild salmon with the salmon farming industry in the region. Progress on the file was halted due to the Canadian federal election in 2019. We await word on when action will reinitiate on the file. Should the programme be reactivated and depending on timing, it might be possible to have some of the equipment installed in 2020.

The Norwegian University of Science and Technology (NTNU) and the Ocean Tracking Network will be installing a small network of acoustic receivers in a fjord system in Southern Greenland (Tasiusaq) in summer 2020. While the prime focus of the work is migration of Arctic charr, any acoustically tagged salmon that venture into the area will be recorded and reported.

With regards to adding acoustic receiver capacity of / to marine autonomous vehicles, OTN has added two new Slocum Gliders and one SV3 Wave Glider to its fleet, and is planning on adding an additional 1-2 Wave Gliders to increase North Atlantic Ocean receiver coverage especially in areas where moorings are logistically difficult or costly to maintain. OTN continues working within the nascent Ocean Gliders Canada and international partners to arrange to place acoustic receivers on gliders operating within marine areas used by salmon during their marine migration, including the Labrador Sea. OTN has also been working through the Horizon 2020 AtlantOS program to partner with a variety of agencies and programs (DFO, OSNAP, OceanSITES, University of Washington, others) that have established fixed moorings in the North Atlantic Ocean and Labrador Sea to add acoustic receivers to the moorings.

Through the Canada Atlantic Salmon Research Joint Venture, the Nova Scotia Salmon Association, DFO, NOAA, OTN and the Atlantic Salmon Federation (ASF) funding was secured to model the efficacy of candidate line arrays and grid structure. A movement ecology modeller was hired and a manuscript describing designs on the Labrador Shelf is expected in 2020. Next steps will be to advance the design work by incorporating current and temperature metrics to advise on the efficacy of different glider and likely drifter paths. This work will continue into 2021.

Prognosis and future developments

- continue to look for cost-efficient opportunities to expand or add new acoustic receiver lines in the Northwest Atlantic;
- continue to look for opportunities to expand and utilize the OTN marine autonomous vehicle fleet; and
- continue efforts to model the efficacy of line arrays and grid structures to monitor the marine migration of Atlantic salmon in the Northwest Atlantic. Results from these modelling efforts will allow researchers to evaluate the efficacy of future open ocean acoustic-based efforts.

3. Platforms of Opportunity in the NAC area: Stationary Platforms of Opportunity Receiver Exchange (SPORE)

Project description: Receivers deployed on existing buoys and platforms associated with collection of environmental monitoring (oceanography and weather buoys) and offshore commercial enterprises (fishing, aquaculture, offshore energy etc.) can be a cost-effective way to obtain baseline acoustic monitoring data. These associations of fish location data with environmental data provide an opportunity to exchange information and expertise with oceanographers and others to better understand seasonal salmon distributions in changing oceans.

Update on Progress (John Kocik): NOAA maintained extant opportunistic arrays in 2019 and worked to connect OTN with the NOAA whale passive acoustic group. Due to workload and funding considerations, work was focused within the Gulf of Maine region. All ocean observing buoys in the University of Maine program (i.e. Gulf of Maine Ocean Observing System) are fitted with acoustic receivers for year-round monitoring. In addition, the inner Penobscot Bay area is monitored from April-December annually. More than 20 other species, including Atlantic salmon, have been detected to date on this vast Gulf of Maine acoustic platforms of opportunity network. These data are retrievable through the Ocean Tracking Network Data portal: Gulf of Maine NEFSC NERACOOS-GoMOOS Buoys (https://members.oceantrack.org/OTN/project?ccode=GMG). Additional partnerships (e.g. lobster fishers) are being considered and could expand coverage seasonally. Expansion of opportunities in the northwest Gulf of Maine and associated waters of the Bay of Fundy remains a mutual NOAA and DFO goal.

Prognosis and future developments: Continue to look for opportunities to expand the Gulf of Maine acoustic platforms of opportunity network. Efforts will remain focused on the Gulf of Maine region, which may provide benefits to US Atlantic salmon monitoring efforts in addition to numerous other species that migrate through the Gulf of Maine, but will provide limited benefit to non-US salmon population monitoring efforts. However, knowledge of highly migratory predators that move north concurrent with salmon migration will be useful for assessing threats to Atlantic salmon.

4. NAC kelt satellite tagging

Project description: PSATs offer the ability to provide information on stock-specific migration routes, behaviour and mortality of post-spawned Atlantic salmon kelts. When combined with results from ongoing post-smolt acoustic telemetry projects, insights may also be gained into the commonalities of kelt and post-smolt migration patterns.

Update on Progress (Tim Sheehan and Jon Carr): The ASF has been releasing acoustic and PSAT tagged kelts into various Gulf of St. Lawrence river systems for a number of years. Efforts have been focused on the released tagged kelts from the Miramichi River system but tagged kelts have also been released into the Restigouche (acoustic and PSAT) and Cascapédia (acoustic) rivers. A 2017 article was published, which reported results from the Miramichi River tagging project. Another article was published in 2019 that investigated ocean predation events from PSAT tagged Miramichi and Restigouche salmon, as well as salmon stocks from 4 European countries. Reduced tagging efforts have continued on these systems, but resources have been re-allocated towards sub-adult PSAT tagging efforts at Greenland and therefore no new domestic kelt tagging efforts outside of the Gulf of St. Lawrence in Canada or the USA have been initiated.

Prognosis and future developments

- plans were underway between ASF and Fisheries and Oceans Canada to track Cascapédia River kelts with 10 PSAT and 25 acoustic tags in spring 2019;
- presently, a multi-partner application led by DFO (M. Robertson) successfully passed through the Letter of Intent phase and a full proposal is being submitted to the Environmental Studies Research Fund to track Atlantic salmon kelt from multiple rivers in eastern Canada beginning in 2021 using acoustic and PSAT tags through areas off Canada's east coast where offshore oil and gas production/exploration is occurring; and
- unless new resources are identified, there is a low likelihood of kelt tagging being initiated in any US river systems.

5. Generic Index River Sites in the NEAC area

Project description: The proposal would be to establish at least four index sites (build on existing index rivers and / or establish new index rivers) spread over the NEAC area, with the aim of quantifying marine survival from leaving to returning to the river; quantifying where the mortalities occur by partitioning mortality among river mouth/estuary, near coastal area, and the remaining stay at sea; quantifying variation in mortality among years; and analysing critical periods for mortality and possible causes of mortality.

The EU-funded SMOLTrack projects carry out much of this work. Progress is reported under the EU-funded projects section below.

6. Malin Head to Islay Receiver Array (NEAC)

SALSEA-Track Project description: The development of telemetry receiver arrays in the North Atlantic / Irish Sea area would allow researchers to investigate a number of key issues impacting the productivity of a number of United Kingdom and Irish Atlantic salmon stocks and other marine species migrating through this area. Key questions to be addressed are: what is the mortality during the early marine phase of Foyle, and Irish Sea salmon; what is the usage of the north channel by basking shark and other elasmobranchs; what is the usage of the north channel by cetacean species; what is the movement of sea trout in the north channel?

Progress Report: This work is integrated into 'SeaMonitor' project and COMPASS project.

SeaMonitor Project Description: In December 2018, the project was successful in securing €4.6 million in funding in an INTERREG VA (Ireland, N. Ireland and Scotland) call resulting in the formation of the SeaMonitor project.

Led by the Loughs Agency, a cross border UK / Ireland body, the project has nine partners: i.e., Loughs Agency (UK, Ireland), Marine Institute (Ireland), Queens University Belfast (UK), Agri-Food and Biosciences Institute for Northern Ireland (UK), University of Glasgow (UK), University College Cork (Ireland), Galway-Mayo Institute of Technology (Ireland), Ocean Tracking Network - Dalhousie University (Canada), and University of California Davies (USA).

The INTERREG VA SeaMonitor project is a novel and comprehensive project focusing on a wide range of issues across the Programme Area (Scotland, Ireland and N. Ireland). It will directly deliver the INTERREG V objective of developing cross-border capacity for the monitoring and management of marine protected areas and species. It will result in a corresponding increase in cross-border monitoring and management capacity. This will facilitate the development and growth of a regional 'blue economy' based on its maritime resources and the alignment of regional activities with the EU's Atlantic Strategy through the potential of e.g., developing and strengthening the growth of marine tourism, providing management plans and enabling sustainable development to occur in often sensitive environments.

The project will deliver five models, three management plans / groups, two of which relate directly to salmonids (i.e. management plan for salmon in the Foyle and Clyde) and extend the INTERREG VA COMPASS network of buoys from the east coast of the island of Ireland to the north establishing a physical connection of acoustic receivers between the island of Ireland and Scotland thus providing a tangible monitoring network to the INTERREG programme. SeaMonitor has been jointly developed by all the partners and will be jointly implemented with partners working together across a range of activities.

SeaMonitor will establish a network of buoys for regional seas, including telemetry and oceanographic monitoring (e.g. for seals, cetaceans and salmonids).

Salmonid Elements of SeaMonitor update (Ross McGill and Niall Ó Maoiléidigh): A total of 108 Acoustic Listening Stations (ALS) are planned to be deployed at different locations across the North Channel from Malin Head to Scotland (Islay), aka 'the Main array', to detect the presence of acoustically tagged fish and marine mammals. Ship time from the Marine Institute's RV Celtic Voyager for this element of the project has been scheduled for February / March 2020.

A further 40 ALSs are planned for deployment in coastal areas (Foyle estuary, west coast Donegal, North Coast of N. Ireland) to detect not only salmonids but skate and basking sharks. Acoustic cetacean monitors will also be deployed in the region.

Tagging of salmon will take place from several locations in N. Ireland (Bush and Foyle), Scotland (Clyde) and Ireland (Burrishoole, Boyne, Shannon and Lee). The aim is to tag a minimum of 250 smolts per year across the target rivers of the project.

All procurement for the staff, receivers and tags is complete. Operational details have been organised with the Marine Institute Ocean Science Services (Research Vessel Operations). Animal welfare licences haven been received for the project and for the individual tag teams.

The locations of the main and the Foyle acoustic listening stations are detailed below (Figure 1). The receivers will be serviced in September 2019 and redeployed.

Figure 1. Locations of acoustic receivers for SeaMonitor project

Communications: Excellent synergies and collaboration have also been made between the three INTERREG VA funded marine research projects (SeaMonitor, COMPASS, MARPAMM) in terms of communications. Discussions are taking place on a joint website and joint conference in 2020. There is a Twitter account (@SeaMonitor1) with over 250 followers.

SeaMonitor attended the European Tracking Network (ETN) meeting in Palma Spain 15-17 October and is now a member. It has recently been agreed that the project will host the next annual meeting of the ETN in Derry N. Ireland in November 2020. SeaMonitor also recently attended COMPASS and MarPAMM annual meetings.

The project would like to invite any and all institutions outside of the project that have tagged or intend to tag marine species with acoustic transmitters in the region to send us their information so that they can trace any transmissions downloaded from the SeaMonitor arrays and share data accordingly.

Salmonid Elements of the 'COMPASS' Project

Northerly route for salmon smolt migration out of the Irish Sea confirmed

The INTERREG VA COMPASS Project compliments the SeaMonitor Project in addressing the SALSEA Malin Head to Islay Receiver Array (NEAC) Outline Project. The Salmonid Workpackage of the COMPASS project is to identify and define the habitats used by outward migrating salmon and resident marine phase sea trout through a network of moored acoustic receivers. The critical issue for both species is population decline, without full knowledge of cause.

Progress Report: Results to date from this acoustic telemetry study have revealed, for the first time, a northerly migration route for Atlantic salmon (*Salmo salar* L.) smolts leaving rivers on the north east coast of Ireland. Atlantic salmon smolts were tagged in Spring 2019 in the Castletown and Boyne rivers (Fig. 1). Three tagged smolts registered on disparate marine receivers as they travelled northwards out of the Irish Sea through the North Channel. One of the smolts was recorded in Scottish waters, some 80 kilometres north of the Inishowen Peninsula. This smolt had travelled an estimated 250 kilometres in just over a month, one of the longest distances recorded for a salmon tracked at sea en route to its feeding grounds in the North Atlantic. A further two individuals were tracked as far as receivers located off the Northern Ireland coast, further confirming the northward migration of salmon smolts through the Irish Sea.

Arising from this result a new array (Fig. 2) is being deployed across the central channel between Larne and north of Stranraer (Scotland) in February 2020 to extensively monitor tagged salmon kelt and smolt migrations from the River Boyne.

Project team: James Barry, Richard Kennedy, Robert Rosell and William Roche

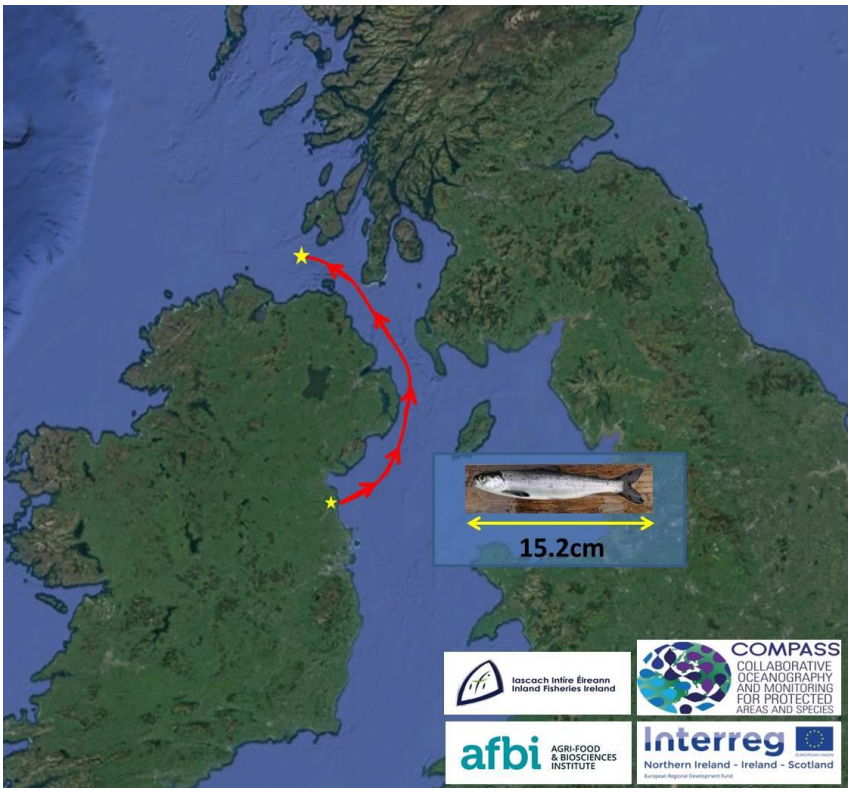

Figure 1. *Reconstructed track of salmon smolts out of the Irish Sea in 2019*

***Figure 2**. Location of acoustic receiver array to be deployed by COMPASS in Feb 2020*

7. North Sea Loose Array (NEAC)

Project description: A broad distribution of receivers deployed on existing platforms and moorings in the area between Scotland and Norway may provide partial coverage of a relatively narrow area sectioning the North Sea from the Atlantic. Possible sites could be oceanographic and weather buoys and particularly offshore commercial enterprises (fishing, aquaculture, offshore energy, etc.). Some of these will provide environmental monitoring in addition to acoustic monitoring data. The aim is to use these opportunities to cover approximately 30% of the area along a rough line from Northern Scotland to Southern Norway.

Progress Reports for this project have been requested annually since the telemetry workshop, but none have been received.

8. West-Coast Scottish Arrays (NEAC)

Project description: Plans for tracking smolts are currently being prepared as part of programme of work involving Marine Scotland Science and the freshwater fisheries and aquaculture sectors. The initial focus has been into possible interactions between aquaculture and wild salmon with the establishment of experiments using fish treated with agents that kill parasites. This work is being coupled with models of lice dispersion from salmon farms. Salmon smolts have already been tracked in a pilot project in Loch Linnhe. The possibility of extending that work to develop models of salmon dispersal patterns is being assessed. There is also an early stage assessment of the feasibility of establishing a curtain of acoustic listening devices between the Hebrides and mainland Scotland.

Progress Report (John Armstrong, Mark Bilsby and Alan Wells): At present there is little information on the distributions of salmon smolts over time as they leave the Scottish coasts. Such information is important for informing spatial planning decisions, particularly in relation to salmon aquaculture. It is impractical to track salmon smolts from many river systems and hence there is a need to develop a general model of dispersal. To this end, Marine Scotland Science has developed particle tracking models that predict dispersal depending on swimming vectors of smolts, coupled with local water currents. It is now necessary to ground truth such

models by experimental determination of swimming vectors and empirical estimates of smolt movements and distributions at sea.

The Atlantic Salmon Trust, Fisheries Management Scotland and Marine Scotland Science are collaborating to oversee a project to start to map locations of acoustically-tagged salmon smolts at sea. Glasgow University are providing field tagging teams in support. This project is designed to be capable also of detecting smolts tagged in the EU SeaMonitor project being conducted to the south.

In 2020, an array of receivers will be established extending to the north and south of the Outer Hebridean Islands and between the islands. A further array will be deployed within the Minch. Smolts will be captured and tagged in a number of rivers in the west and south-west of Scotland. The main objectives at this pilot stage will be to determine whether the arrays pick up tags and are capable of differentiating among several possible swimming vectors. It is anticipated that as a next stage (subject to availability of funding), a grid array of receivers will be deployed within the Minch to refine further the actual swimming vectors of smolts and so develop a dispersal model that can be used for planning.

9. Studies of migration along the European shelf edge and into the Norwegian Sea using drifters/AUVs etc (NEAC)

Project description: A particle drift model, developed as an output from the SALSEA Merge project (2009 to 2011), indicated a strong likelihood that most southern European post-smolts (Spain, France, Ireland and UK) use the European shelf edge current as a marine 'highway', following currents to summer/autumn feeding grounds in the Norwegian sea. The SALSEA-Merge model assumed that much of the movement of post-smolts was a result of passive transport. This model and the associated hypotheses surrounding the migration paths of southern European post-smolts should be tested to see if it accurately portrays smolt migration, particularly in areas where smolts leaving freshwater have to migrate significant distances against the residual coastal and oceanic currents. Similarly, wind driven currents could have marked effects on migration routes and more information on movements of post-smolts in key areas would greatly assist in developing such models further. Potential methods to test the current migration hypotheses include deploying acoustic tag detection systems on a range of bioprobes, drifters, autonomous underwater vehicles (AUVs also known as gliders), oceanographic buoys, ocean monitoring stations and buoys attached to fixed fishing gear. Deployment of fixed receivers on oceanic platforms or establishing oceanic monitoring stations would be difficult in areas where the shelf edge was distant from the coastline. Where the shelf edge was closer, e.g. off the North West of Ireland, such platforms or arrays could be considered which would allow tracking of post-smolts from Spain, France, Ireland and the UK. Fixed moorings could be employed on the shelf and potentially on the upper continental slope. Alternatively, deployment of AUVs would allow strategic tracking of post-smolts at key points along the shelf edge which narrow to only 10s or 20s of kms. These AUVs would allow confirmation of pre-suppositions relating to the use of the shelf edge as a marine 'highway' as well as providing information on survival of electronically tagged groups of post-smolts released from each of the southern European salmon producing countries.

Progress Report: This is integrated into 'SeaMonitor' project (for further information see project number 6. Malin Head to Islay Receiver Array, above).

Project Update (Ross McGill and Niall Ó Maoiléidigh): The SeaMonitor project will concentrate on use of an AUV rather than drifters and will focus initially on the shelf edge northwest of Ireland and west of Scotland. The AUV has been ordered and is expected to be in service by May of 2020. The initial trials will allow range testing of onboard acoustic receiving

capabilities for smolt tracking. The Marine Institute's vessel Celtic Voyager will allow the AUV to be deployed along the shelf edge during May and June at strategic locations to opportunistically locate migrating tagged smolts and to refine the smolt migration model developed under the SalseaMerge project.

The AUV will then be used to profile the shelf edge for current speed and other dynamics using an ADCP and other on board profiling equipment.

Project duration: The project end date is 31 Dec 2022. The array will be deployed for this period and will allow release of tagged smolts in 2020, 2021 and 2022 for subsequent tracking. The AUV will be used in strategic locations of previously identified post-smolt migration during the same period to opportunistically locate migrating tagged smolts and to provide data to model the migrations of salmon in the ocean in the early stages of the migration using behavioural and oceanic parameters.

10. NEAC kelt satellite tagging

Project description: Atlantic salmon kelts from different rivers migrate in spring to feeding areas before returning after one or more years. Kelts from different rivers use separate feeding areas that are defined by oceanographic processes which vary from year to year. The use of satellite tags will allow researchers to address: the extent of fine-scale population mixing / segregation in the ocean; stock-specific and population structure (spatial and age) migration strategies; mortality / success in relation to habitat occupation in feeding area; return/ predation rates and type; migration dynamic linkages with oceanographic conditions.

Progress Reports for this project have been requested annually since the telemetry workshop, but none have been received.

11. Sub-adult satellite tagging at Faroes

Project description: The application of PSATs to salmon captured and released at the Faroe Island, combined with genetic assignment techniques, will allow researchers to investigate: the partitioning of mortality between life stages; the extent of fine-scale population mixing/segregation in the ocean; stock-specific and population structure (spatial and age) homeward migration strategies; mortality / success in relation to habitat occupation in feeding areas; return/ predation rates and type; and migration dynamic linkages with oceanographic conditions.

Progress Reports for this project have been requested annually since the telemetry workshop, but none have been received.

12. Adult satellite/acoustic tagging at Greenland

Project description: This technology, in combination with genetic assignment methods, offers the ability to provide information on stock-specific migration routes, behaviour and mortality during the second year at sea.

Progress report (Tim Sheehan and Jon Carr): A five-year collaborative study was initiated in 2018 by the Atlantic Salmon Federation (Canada), NOAA Fisheries Service (USA), Fisheries and Oceans Canada, and the Association of Fishers and Hunters (Greenland) to track salmon fitted with pop off satellite tags (PSATs) from Greenland to coastal regions of origin. Funding for the project is provided by primary as well as additional project partners (e.g. Equinor, Canada's Atlantic Salmon Research Joint Venture and the Atlantic Salmon Trust).

Tagging occurred from September-October in 2018 and 2019 near Qaqortoq Greenland. Atlantic salmon are primarily captured via trolling and tagged with PSATs (Microwave

Telemetry Inc. (Colombia, Maryland) X-tags). Genetic assignments were conducted for all tagged fish to determine region of origin.

In 2018, a total of 17 Atlantic salmon were captured; 12 were tagged and released with PSATs, 2 with acoustic tags and 3 were not tagged but only sampled. Of the 12 PSAT-tagged salmon six individuals were identified as North American origin and 6 were identified as European origin. For the North American origin salmon, one was identified as originating from the USA reporting group, 4 from the Gaspé Peninsula reporting group, and 1 from the Ungava Bay reporting group. All 6 European origin salmon were identified as originating from the United Kingdom / Ireland reporting group. A total of 8 tags popped off and transmitted collected data. Data are currently being processed and analysed.

In 2019, a total of 25 Atlantic salmon were captured; 20 were tagged and released with PSATs, 4 with acoustic tags and 1 was not tagged but only sampled. Genetic assignments results to determine region of origin are not available yet. As of December 2019, 4 tags had popped off and transmitted data. Tags are programmed to remain active until May 2020. Shortly after that date, all data from the 2019 tagging effort will be in hand and will be processed and analysed.

Fishing in the Qaqortoq region appeared to be poor in 2018 and 2019 based on anecdotal information received from local fishers and low trolling catch rates. Exploratory trolling in 2017 resulted in ~1.43 fish caught per trolling hour compared to the ~0.15 salmon caught per hour in 2018 and 2019.

The five-year study referenced above focuses on the use of 'traditional' PSATs and light-based geolocation to map migration routes of tagged salmon. The ASF and NOAA is also partnering with researchers from the Woods Hole Oceanographic Institute (WHOI), among others, on the development and testing of the ROAM (RAFOS Ocean Acoustic Monitoring) approach to marine tracking.

ROAM is an acoustic tracking system where low frequency long ranging sound wave "pongs" are emitted from ocean moored sound sources and received by a tag equipped with a hydrophone attached to the study animal. A primary advantage of the ROAM approach is the long range of the "pongs" which could result more accurate geolocation over a wider spatial and temporal range compared to traditional light-based methods. However, it should be noted that this technology is in the early stage of development and field testing is ongoing.

Prognosis and future developments

- the primary project partners (ASF and NOAA) have developed a five-year project plan (2018-2022) and barring any unforeseen circumstances or outcomes will continue to implement that plan;
- in 2020, the sampling period will remain from September through October, taggers will be scheduled to minimize overlap and maximize days fished, efforts will be put forth to increase the fishing effort via additional fishing vessels, and efforts will be put forth to explore the efficacy of shore-based gillnetting to increase access to adequate numbers of salmon towards the objective of tagging 50 salmon with PSATs annually;
- ASF and NOAA continue to seek opportunities and communicate with potential future partners to develop a robust acoustic monitoring network in the region to expand current acoustic tagging efforts for Atlantic salmon and other species captured at Greenland;
- project partners continue to pursue additional funding opportunities to supplement and continue this work; and

- ASF and NOAA will continue to work with the Woods Hole Oceanographic Institute on the development and testing of the ROAM (RAFOS Ocean Acoustic Monitoring) approach to marine tracking and if appropriate will transition from traditional light-based PSAT tags to ROAM PSAT tags.

B. Projects Supported by EU Funding to the Board

Four projects have been funded through the EU's 'Grants for an action'. A summary of the projects is provided below.

SMOLTrack I: Understanding and comparing early mortality of European salmon populations at sea

Project description: In this set of projects, hands-on salmon scientists have tagged and tracked salmon smolts and kelts with both acoustic, radio and PIT tags. To date nine countries are participating and the project covers the entire distribution areas within EU (from Portugal in South to Finland in North). SMOLTrack I and SMOLTrack II are complete and SMOLTrack III commenced in January 2020, for two years. The SMOLTrack website provides further information.

SMOLTrack I is now compete. It focussed on the initial migration of salmon smolts towards the ocean. Salmon has a wide distribution. Comparing results from studies performed in different geographic areas is inherently difficult and, therefore, requires a common methodology. To achieve this, a similar telemetry approach was developed and applied in different geographical areas. Before tagging, the partners developed standard operating procedures (SOP) for the capture, handling and tagging of smolts to ensure as much comparison as possible between the different study areas. This SOP has been used by all partners during the tagging, except in one of the rivers in Spain (River Ulla). The refined SOP will be made publicly available and may serve as a proxy description for other institutions also aiming at tagging Atlantic salmon smolts with transmitters to facilitate comparison in future studies.

Wild salmon smolts were caught and carefully tagged with acoustic transmitters and then released. The tagged smolts were detected as they moved past Automatic Listening Station (ALS) arrays on the way from their natal river to the open sea. This project setup was carried out in five areas spanning almost the entire North – South distribution area in the EU (Denmark, England, Ireland, Northern Ireland and Spain).

Table 1. *Fate of the released smolts for each study area. The percentage of smolts successfully crossing the study area is shown in brackets in the last column.*

Country	River	Smolts released	Smolts lost	Successful smolts
Denmark	Skjern	86	55	31 (36%)
England	Tamar	100	36	64 (64%)
Ireland	Erriff	40	28	12 (30%)
Northern Ireland	Bush	99	61	38 (38%)
Spain	Minho	50	23	27 (54%)
Spain	Ulla	100	95	5 (5%)
		∑ = 475	∑ = 298	∑ = 177 (37%)

The SMOLTrack I project revealed variable, but generally low, survival rates in the lower freshwater and transition environments through study areas across the European area of distribution of the Atlantic salmon. The methodology applied worked well and it was possible to acquire highly valuable data sets about loss of salmon smolts in lower rivers / estuaries, comparable over several countries.

The results directed attention towards the conditions under which the smolts must move from river to sea as well as the presence of multiple predators. The results provide a solid, comparable one-year estimate on the survival of salmon smolts through the lower river and estuary / fjord from 6 river systems in 5 countries. The results show that potential bottlenecks for Atlantic salmon exists already in the initial migratory phase, which may have a large impact on the overall return rate of adult salmon.

SMOLTrack II: Comparing mortality of European salmon populations at sea using multiple-method telemetry studies

SMOLTrack II is now complete. It aimed to gain more detailed knowledge about potential bottlenecks and underlying causes for low survival during smolt migration and to describe the potential inter-annual variation. A summary of the five objectives of the project is provided.

Objective 1. Comparisons between survival of wild and hatchery-reared salmon smolts: Preliminary analyses of the numbers of fish lost before migrating through each study area are presented in Table 2. The results reveal generally low survival. Overall 33% of wild smolts and 39% of hatchery smolts which were acoustically tagged were successful. 36% of wild smolts that were radio tagged were successful. Hatchery reared fish appear to perform slightly worse than wild fish in most direct comparisons, but the high survival of hatchery fish in River Taff (where no wild fish could be tagged) and the Erriff, actually raises the overall hatchery survival above the wild survival.

***Table 2**: Number and percentage of smolts successfully crossing the study areas.*

		Successful smolts	
Country	**River**	**Acoustic (Wild / Hatchery)**	**Radio (Wild)**
Denmark	Storå	39/30 (78%/60%)	-
England	Taff	-/57 (-/61%)	-
Ireland	Erriff 2018	17/25 (49%/71%)	7 (23%)
	Erriff 2019	16/- (80%/-)	20 (47%)
N. Ireland	Bush	13/12 (26%/24%)	24 (71%)
Spain	Minho	8/13 (36%/27%)	-
Spain	Ulla	1/0 (1%/0%)	0 (0%)
Sweden	Göta Älv	7/11 (29%/23%)	-
Sweden	Hogvadsan	-/12 (-/32%)	-
		∑ = 101/160 (33%/39%)	∑ = 51 (36%)

Objective 2. To identify and describe the causes for smolt loss using radio-telemetry: In the Skjern River, salmon and sea-trout smolts were captured and tagged with 23 mm PIT tags in two seasons. A total of 1184 smolts were PIT-tagged and the subsequent search for tags in three cormorant colonies provided estimates of the rate of predation on the PIT tagged smolts. The estimated predation rate for salmon was 12%. Additional PIT tagging has been carried out in the Erriff and awaits surveys of bird colonies in the general area and monitoring of adult salmon returns.

Objective 3. Pilot study to test the feasibility to tag genetically assigned immature salmon at the Faroe Islands or Greenland: This part of the project was not carried out because it proved impossible to get access to any east Greenland, Faroes or Svalbard fishing operation and the cost of establishing a dedicated experimental fishing was too high for the project. A change to the project in light of this was proposed and accepted by the EU. This is set out in the next section.

Objective 4. Blood sampling to evaluate smolt quality as they exit rivers: Blood sampling of a subsample of the salmon was conducted, to develop key biological markers (biomarkers) for

Atlantic salmon. It enables investigation of the underlying physiological readiness for migration and life at sea, a potential explanatory reason for variable survival. A blood sampling protocol was drafted to ensure method compatibility. Overall blood samples were taken from 103 wild fish and 85 hatchery fish.

Objective 5. Work with a Swedish partner to extend geographic range of the work: As can be seen in the information provided in the next section a Swedish partner was included in the project. This allowed data for the Göta Älv and Hogvadsan Rivers to be included in the study.

The results from this project provide a solid estimate on the survival of salmon smolts through the Lower River and estuary / fiord from eight river systems, comparable to the results of the last iteration of the project. Migration behaviour, timing and possible bottlenecks have been revealed from the data. Several partners have already made arrangements for a study extension within the present project (by using available infrastructure and adapting to the findings in the present project) and additional funding is sought to include more countries (Finland and Portugal) and extend the studies in the existing areas. An interesting avenue forward would be to see if transporting salmon smolts downstream of any mortality hotspots may alleviate the challenge.

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

SMOLTrack III began in January 2020 and runs for 36 months. 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 EU-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 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) will comprise the project: WP1 Eval-smolt - designed to better understand and quantify the principal factors affecting smolt

survival during their migration through the freshwater environment and transition to the marine environment; WP2 Thermo-smolt - designed to better understand and quantify the thermal influence on smolt-migration timing; and WP3 Hand-smolt - designed to better understand and quantify the accuracy of telemetry-based assessments to provide information on smolt-migration habits and evaluate survival.

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

The existing SMOLTrack partnership, together with its new partners, has extensive experience in migratory fish research and particularly telemetry studies. The distribution of experienced project partners, across the wide latitudinal distribution of salmon in Europe, will allow the project to investigate salmon under varying climatic ranges. SMOLTrack I & II have already produced several important research outputs and aim to advance understanding further through SMOLTrack III.

LICETrack: Sea lice model for the sustainable development of Atlantic salmon fisheries and aquaculture

LICETrack was funded from January 2017 to September 2019.

The project has successfully developed a spatially and temporally highly-resolved baroclinic / barotropic hydrodynamic model for the Killary Harbour project area. This has been coupled in an offline fashion with a sea lice dispersal model for Killary.

The project has demonstrated that the Norwegian Lagrangian Advection and Diffusion Model (LADIM) model can now be linked to virtually any hydrodynamic model. The LADIM model was successfully applied to Killary. The model is required to objectively risk assess the potential impact of salmon aquaculture installations and associated sea lice dispersal on wild salmonids in a particular area. As applied here, this model is specific to the salmon louse *Lepeophtheirus*. The model structure has also been designed in modular form for adaption to model other active and passive water-borne particles such as viruses, microplastics and other pollutants emanating from aquaculture installations as part of a whole-bay management approach.

The project has developed a standardised modelling framework to model sea lice dispersal to support the sustainable management and development of environmentally-sustainable aquaculture and concomitantly support the conservation of wild salmonids (Atlantic salmon and sea trout) based on a refinement of previous and existing models from Norway, Scotland and Ireland.

The project has enhanced the capacity for sea lice modelling in Ireland and provided a better understanding of sea lice transport in Killary Harbour (the National Salmonid Index Catchment) where sea lice mediated mortality from marine salmon farms has been an ongoing pressure to the sustainability on wild salmonid stocks.

The project has demonstrated the versatility of the LADiM model through the coupling of LADiM with a second complex hydrodynamic model (EFDC). It has facilitated the validation of existing models used in Norway and Scotland in new environment.

The production of this standardised modelling framework is considered a major achievement of the project. The project consortium recommends that this standardised modelling framework should be adopted by all NASCO Parties that are developing risk assessments for finfish aquaculture and should be considered in the context of the NASCO document SLG(09)5 *Guidance on Best Management Practices to address impacts of sea lice and escaped farmed*

salmon on wild salmon stocks. The standardised modelling framework will be published as a peer-reviewed book chapter.

Sea lice are considered among the major threats to both wild salmon and sea trout stocks. Infestations of wild salmonids with sea lice from marine salmon farms can act as a moderating pressure on river stocks through increased mortality, and additionally for sea trout, influence their premature return to freshwater. This project has supported the development of an integrative sea lice-hydrodynamic model to predict the dispersal of sea lice from marine salmon farms based on varying environmental and temporal conditions. Overall, the project has developed a standardised framework which offers a more sustainable approach to the management, operation and planning of marine salmon farms which can reduce the risk of sea lice-induced mortality on wild salmonids associated with such practices.

C. New telemetry projects reported through the Inventory of Research relating to salmon mortality at sea.

The Inventory of Research Relating to Salmon Mortality at Sea includes 20 ongoing projects related to the migratory behaviour of individual fish (C16, C18, C25, C27, C31, C32, C41, C50, De4, De5, De7, Ir12, Ir13, Ir14, Ni4, N18, U4, U10, U13, U16). One new project (C50) involving tracking individual fish has been included since last year. Details are provided in the table below.

Party or relevant jurisdiction	Canada
	University of Acadia, Wolfville, Nova Scotia
Title of project	**Atlantic Salmon Research Joint Venture** – Survival, distribution and environmental preferences of Atlantic Salmon smolts (*Salmo salar*), post-smolts and kelts, from the inner Bay of Fundy, Nova Scotia.
Objective of research project	There is an opportunity to use existing acoustic receiver infrastructure, deployed to study Atlantic Salmon (*Salmo salar*) smolt dispersal, migration and survival by Acadia, DFO, OTN and FORCE, to also examine these parameters for post-spawning adults (kelts) from the Gaspereau River.
Brief description of research project	Objective 1 - use acoustic tag technology to determine the migration and dispersal of Inner Bay of Fundy (IBoF) smolt, post-smolt and kelts released in the Gaspereau River, Nova Scotia. Objective 2 - For all life stages we will determine predation / mortality rates in freshwater and marine environments.
Dates during which research will take place	April 1 2019 to March 31 2020
Area in which research will take place	Bay of Fundy, eastern Canada
Board Topic Area	Distribution / migration in the sea: migratory behaviour of individual fish
SALSEA Work Package	WP3: Investigating the distribution and migration of salmon at sea - Task 3: salmon at sea: carry out a comprehensive survey

	- marine surveys / acoustic tagging surveys / data storage tags / others
Estimated number and weight of salmon to be retained	25 female kelts were retained at the Live Gene Bank hatchery in Coldbrook, N.S. (Mean ± SEM, L_F= 0.63 ± 0.011 m, Age = 4 years) Weight N/A
Resources	
Estimated cost of the research project in 2020	The direct cost of the research project is £39 K. The cost of the full project including in-kind for receivers and deployment costs is substantially more.
Number of participating scientists	4
Name and e-mail address of co-ordinating scientist in charge of project	Dr. Michael J. W. Stokesbury, Canada Research Chair in the Ecology of Coastal Environments & Professor, Biology Department, Acadia University, Canada michael.stokesbury@acadiau.ca

Conclusion

At the Annual Meeting of the Board in 2019 (CNL(19)09), it was agreed that a Working Group would be established to review both the Inventory and SALSEA-Track programme. The Working Group met in February 2020. In its report to the Board, the Working Group has made a number of recommendations, including that the SALSEA-Track Programme, in its current form, should be closed.

The Board will consider these recommendations at the 2020 Annual Meeting. The Report of the Working Group (which includes the full recommendations) and the Report of the Annual Meeting of the Board (which will detail the response to the recommendations) will be posted on the Board website before and after June 2020, respectively.

Chair of the Board and Secretariat
Edinburgh
6 April 2020