SAG(14)4

Report of the SAG Sub-Group on Telemetry

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Meeting held by correspondence, Sept 2013 – May 2014

1. Introduction

1.1 In December 2012, a Sub-Group of the IASRB's Scientific Advisory Group (SAG) met to:

- review the IASRB's Inventory of Marine Research and the progress made on projects to date, and
- identify gaps in research efforts and knowledge which may be important for advising on salmon management actions.

1.2 The Sub-Group reported on the useful contribution that work on the marine phase of the salmon life-cycle had made in supporting salmon management. However, it noted that, with exception of specific research efforts in the North American Commission area to estimate migration routes and survival of early stage post-smolts from a small group of rivers, research efforts in SALSEA had not provided the data to identify the presence, timing and location of survival bottlenecks of salmon for different stages during the marine phase. The Sub-Group therefore recommended that a particular focus for future research supported by the IASRB should be studies to partition marine mortality among the phases of the marine migration of salmon.

1.3 This was discussed by the IASRB at its meeting in June 2013 and it was agreed that in order to take forward the collaborative international programme of research, a SAG Telemetry Sub-Group should be established under the Chairmanship of Ted Potter (EU). This Sub-Group would work by correspondence (or hold a workshop, possibly partially supported by funding from IASRB) to develop and document a roadmap outlining a large-scale international collaborative telemetry project to ultimately provide information on migration paths and quantitative estimates of mortality during phases of the marine life-cycle of salmon from across the North Atlantic.

2. Terms of Reference

2.1 Specifically, the Sub-Group was asked to '*work by correspondence (or hold a workshop, possibly partially funded by IASRB) to develop and document a roadmap outlining a large scale international collaborative telemetry project to ultimately provide information on migration paths and quantitative estimates of mortality during phases of the marine life-cycle of salmon. This document will:*

- *identify how this project will support the conservation and management of Atlantic salmon stocks (i.e. what outputs will be produced and how these will improve Atlantic salmon management);*
- *provide an overview of the resources required with provisional costings;*
- *identify key strategic partners for this project;*
- *identify current and proposed telemetry programmes that could be linked with and enhanced by the proposed project.*

2.2 Parties were asked to nominate members for the Sub-Group, and these are listed below:

Gerald Chaput	Canada
Peder Fiske	Norway
Peter Hutchinson	NASCO
Niall O ´ Maoiléidigh	EU
Ted Potter	EU (Chairman)
Sergey Prusov	Russian Federation
Tim Sheehan	USA
Ken Whelan	NGO (Europe)
Dave Meerburg	NGO (North America)

2.3 The Sub Group conducted its work by correspondence between September 2013 and May 2014.

3. Roadmap for International Collaborative Telemetry Project

3.1 The Sub-Group developed a roadmap for an international acoustic tracking programme, describing: the objectives of the study and its potential benefits; the experimental methods, equipment and approximate costs; the areas where the study might take place and the potential collaborators and partners; the risks; and the next steps for taking the proposal forward. The roadmap is attached as Annex 1 and summarized below.

3.2 The aim of the international acoustic tracking programme will be:

- to monitor the progress of salmon from NAC and NEAC rivers along their migration routes to and from the marine feeding areas; and
- to estimate stage and area specific mortality rates of these salmon during the marine phase of their lifecycle.

3.3 The programme will build on studies carried out in the Gulf of Maine, USA and Gulf of St. Lawrence, Canada in which emigrating salmon smolts have been tagged with acoustic transmitters. These fish have then been detected passing arrays of receivers in the lower reaches of the river, the estuary and in coastal waters, and this has provided estimates of the losses at different stages of this emigration. The proposal is to both extend the North American studies and initiate similar studies in the North-East Atlantic. It will involve both the use of established tracking techniques and the development of new methods to follow post-smolts further out into the open ocean. Tracking studies will also be conducted on returning adult salmon using similar tracking methods used for post-smolts and ideally many of the same receiver arrays.

3.4 The active tracking studies will be supplemented by the use of archival tags which record data on the environment around the fish over periods of months or years. This will include the use of satellite pop-off tags, which are automatically released from the fish after a predetermined time and then transmit their data back via a satellite link. These tags have already been used successfully in studies of adult salmon caught at West Greenland and on salmon kelts from across the North Atlantic.

3.5 International coordination for such a study will be particularly necessary in the North-East Atlantic because many post-smolts emigrate through the waters of multiple jurisdictions, and receiver arrays would ideally be placed at suitable ‘choke points’ in the migration pathway.

3.6 Partitioning the mortality of salmon between different stages of the marine migration and between different areas of the sea, will assist in identifying and prioritizing the factors impacting stocks during this phase of the life-cycle. This is a novel and exciting project proposal that has the potential to answer key questions relating to the conservation and management of Atlantic salmon. It will have a high profile, being dependent upon extensive international collaboration and partnerships between scientists and industry. There is also great potential to collaborate with researchers and organizations focused on a variety of other marine species that utilize the North Atlantic and Arctic Oceans. It will therefore further raise the profile of NASCO as a leader in marine resource management. This is also a very challenging study which, while partly based upon established methods, will also require the development of new methods for detecting tagged fish in the open ocean.

3.7 The roadmap (Annex 1) provides only an outline of the proposed programme, because the details will depend upon a large number of factors including the research agencies that are able to participate, the funding that is made available, the requirements of the funding agencies and many logistical issues. The proposed next steps for the study are listed in the table below.

Summary of Next Steps for the International Acoustic Tracking Programme.

Date	**Who**	**Action**
June 2014	Sub-Group on Telemetry	• Seek SAG/IASRB support in principal for the research programme.
June 2014	SAG/IASRB	• Decide whether to support the proposed programme and the nature of that support. If there is support: • Develop a resolution from IASRB outlining the need for a large scale tracking effort • Appoint co-convenors to establish one or more Workshops, partially funded by IASRB, to discuss the further development of the programme. • Agree clear Terms of Reference for the Workshop(s) • Provide funds to facilitate the involvement in the Workshop(s) of the leaders of key research groups that would participate in a collaborative international programme. (It may be appropriate to have separate Workshops for NEAC and NAC programmes or for post-smolt and adult tagging programmes). IASRB has already agreed to support the workshop (£6,000) but additional funds may be needed • NB: the Workshop need to involve the groups who will potentially undertake the research and so the convenors, with advice from the SAG, should approach the most likely key players and invite them

		to participate.
Autumn 2014	Workshop(s)	Meet to: • Develop an inventory of ongoing and planned marine telemetry studies on Atlantic salmon; • Develop an inventory of ongoing and planned telemetry studies on other species in the areas of the North Atlantic frequented by salmon; • Develop an inventory of the current (temporary and permanent) and planned location of acoustic receiver deployments in the areas of the North Atlantic frequented by salmon; • Recommend areas where collaborative programmes are most likely to provide the best partitioned estimates of mortality of emigrating post-smolts from multiple rivers with an outline of the scale and cost of such studies; • Identify strategic partners that may assist with implementation of proposed new activities • Advise on appropriate linkages with existing or planned ocean tracking programmes, both on the high seas and near shore / in estuaries. • Explore options for tagging adult salmon in the sea and recommend areas where programmes are most likely to provide estimates of mortality; • Establish one or more Steering Committees to develop more detailed plans for co-ordinated telemetry studies in selected areas and to seek funding.
Ongoing	Steering Committees	• Develop detailed research plans for specific areas of the telemetry programme, including tagging sites, location of receivers and receiver arrays. • Estimate costs and timescales for proposed activities • Identify potential research funding sources and seek opportunities for support funding, particularly from Ocean Foundations, industry and other marine conservation bodies. • Formalise links with key industrial (e.g. manufacturers) and strategic (e.g. OTN) partners • Formalise links with strategic partners working with other species that may benefit from collaboration • Outline of tasks to be completed to implement the plan

Annual Meetings	IASRB/SAG	• Review Steering Committee plans and advise on ways to improve coordination between studies • Receive proposals from Steering Committees for potential provision of support as appropriate. • Review progress with the overall programme and determine how to facilitate future activities. • Ensure continued co-ordination of the overall programme.

4. The role of IASRB and SAG

4.1 The SAG Sub-Group on the Future Direction of Research on Marine Survival of Salmon (SAG(13)2) has previously noted that the Board 'had very limited resources and recognized that if it is to continue to play a role in supporting research on salmon at sea it should consider how it can address this situation'. All research in the sea, and particularly that involving the use of vessels in the open ocean, is likely to be expensive, which is why the success of this programme will depend upon large scale international collaboration.

4.2 While the IASRB may not be able to provide significant funding for specific tracking projects, at least in the short term, the Board has a very significant role to play in championing the overall aims of the proposed programme and facilitating collaboration and coordination. Parts of the tracking programme (e.g. operation of index river trapping sites) will be funded from national research and monitoring programmes, but development of large coastal and oceanic acoustic receiver arrays will require funding from international programmes such as EU Horizon 2020. Obtaining such funding will be greatly facilitated by IASRB endorsement.

4.3 Initially, it is proposed that the Board should provide funds to support the attendance of key speakers at a Workshop to bring together research groups that might collaborate in the study. Further development of the proposal will require the formation of research consortia that will plan and cost the detailed requirements for tagging and tag detection systems in different areas.

4.4 The Board may also be able to support and facilitate engagement with research and management agencies working on other species as well as other industrial partners. A formal resolution from the Board stating that it is a priority of the Board to help develop an international collaborative observation programme for marine species in the North Atlantic, with specific reference to Atlantic salmon, would help raise the profile of this effort. This resolution should outline the need for these types of investigations and could challenge the NASCO Parties with identifying funding sources to help develop such a research program. This would be helpful to any group seeking to secure funding from external sources for such a programme. The fact that the SALSEA Programme was developed and endorsed internationally by the IASRB through a public/private partnership was very attractive to potential funders both in the public (e.g. TOTAL Foundation) and private (e.g. European Commission) sectors. The resolution should also highlight the need to base such a programme on existing infrastructures to maximize impact and economy.

Annex 1: Proposal for an international salmon telemetry programme

1. BACKGROUND

There has been a substantial decline in Atlantic salmon stocks throughout much of their range over the past two to three decades despite substantial reductions in exploitation. Total pre-fishery abundance of salmon from North American and European rivers have decreased by over 50% and 60% respectively since the 1970s, and total reported landings have been reduced by over 95%. One reason for the declines has been a substantial reduction in survival of fish during the marine phase of the life-cycle, possibly resulting from natural factors and/or a range of anthropogenic pressures. In order to investigate the distribution and migration of salmon at sea and the factors influencing them, the IASRB developed and has supported a comprehensive programme of marine research - the SALSEA Programme.

In reviewing the various elements of the SALSEA Programme, the SAG Sub-Group on the Future Direction of Research on Marine Survival of Salmon (SAG(13)2) recognized that it had led to major advances in understanding of the distribution and migration of salmon at sea through marine surveys, acoustic tracking, stable isotope analysis and migration modelling. There have also been significant developments in electronic tagging technologies for studying the movements and behaviour of fish, and the Sub-Group noted how these techniques have been applied in studies in the US and Canada to estimate mortality. This work has demonstrated the potential for building on the SALSEA Programme to learn more about the mortality of salmon at sea.

Current estimates of changes in marine mortality are based primarily on the return rates of smolts (usually tagged) after one or more years at sea. This therefore provides very little information on where and when the main losses are occurring. It has been suggested that losses may be greatest during the early stages of the outward migration of smolts (Friedland *et al*. 2009; Thorstad *et al*. 2012), and this may be the time when the fish are most vulnerable to human activities and some forms of predation (e.g. birds). Nevertheless, at present there is very little evidence available to critically evaluate these suggestions.

This paper outlines a proposal for an international programme of research using tracking systems to provide information on the migration of post-smolts to feeding areas and the return journey of adult salmon to their natal rivers and to quantify mortality during different phases of these migrations. The programme will build on the existing infrastructure and historical data sets obtained from: acoustic tagging studies conducted on index rivers in NAC and NEAC areas; SALSEA activities on timing and migration corridors of post-smolts in southern NEAC; advances in acoustic tracking technologies (Whoriskey 2011; Lacroix *et al*. 2011), and additional information from academic, industry and government partnerships.

2. PROJECT OBJECTIVES

Building on the advances already made by the SALSEA Programme, the aim of the proposed project is to establish an international acoustic tracking programme:

- to monitor the progress of salmon from NAC and NEAC rivers along their migration routes to and from the marine feeding areas; and
- to estimate stage and area specific mortality rates of these salmon during the marine phase of their lifecycle.

3. BENEFITS OF PROPOSED RESEARCH ACTIVITY

The use of acoustic tracking technologies has already provided important information on migrating salmonids. The programme will build on the benefits arising from previous acoustic studies, including:

- refining knowledge on specific timing and migration routes and identifying changes between years;
- providing accurate information on locations of experimental animals and, therefore, associated stocks;

- helping to identify choke points (i.e. places where migrating post-smolts are concentrated in space and time) where mortality of migrating post smolts occurs;
- partitioning mortality between near-shore and offshore waters;
- mapping return journeys for larger fish;
- providing direct information on the behaviour of fish in response to changes in environmental conditions; and
- identifying associations between mortality and marine fisheries, shipping, near-shore structures (net pens, wind-farms, oil terminals).

This is a novel and exciting project proposal that has the potential to answer key questions relating to the conservation and management of Atlantic salmon. It will have a high profile, being dependent upon extensive international collaboration and partnerships between scientists and industry. There is also great potential to partner with private sector foundations and NGO groups with an interest in supporting research initiatives and collaborate with researchers and organizations focused on a variety of other marine species that utilize the North Atlantic and Arctic Oceans. It will therefore further raise the profile of NASCO as a leader in marine resource management.

Tracking projects undertaken in the US (Gulf of Maine) and Canada (Gulf of St Lawrence) based on acoustic tagging have demonstrated the potential for such methods to be used to identify the migration routes of emigrating post-smolts and to quantify the mortality occurring during different phases of this migration. Similarly, trials with pop-off satellite transmitters on salmon caught at West Greenland and kelts returning to sea after spawning have demonstrated the potential for elucidating the migration routes and behaviour of salmon at later life stages, including the return migration from the ocean feeding areas towards their home rivers.

While some migration pathways have been identified (e.g. through SALSEA Merge), the identification of the specific natural factors and anthropogenic activities to which salmon are exposed along these migration routes, and which have the potential to adversely impact stocks, will contribute greatly to our understanding of marine survival for post-smolts and adult fish. More detailed information on migratory behaviour for specific stocks will also assist in developing and testing generalised migration models that can then be applied to stocks more widely. Such models have potential to describe probable migration paths under different oceanographic conditions, including the possible effects of climate change.

The proposed telemetry studies will enable partitioning of the total marine mortality between different stages of the marine migration and between different areas of the sea, allowing quantification of the losses that occur in association with mortality factors in specific areas. This will assist in prioritizing these factors and in planning remedial actions where this can be achieved. Examples of specific human activities where these data could support planning and management include salmon farming, marine renewable energy (e.g. wind farms) and the minimization of bycatch of Atlantic salmon in pelagic fisheries.

The study will also identify factors adversely affecting salmon in the sea which cannot be directly influenced by human intervention. However, these factors must be identified in order to monitor changes in stocks status and manage them accordingly.

4. ACOUSTIC TELEMETRY PROGRAMMES

Telemetry is the automatic collection and transmission of data by radio, acoustic or other means from a remote source. In the case of fish telemetry, this is undertaken using electronic 'tags' attached to the animals. Two broad categories of tags are used to collect data on free swimming fish in the sea and are relevant to the proposed study:

- acoustic transmitters which transmit a regular acoustic ping, which is often coded; these tags allow the fish to be actively followed with mobile receivers or passively detected passing fixed (or potentially mobile) receivers;
- archival (or data storage) tags which collect and record biological and environmental data as the fish migrate; the data are recovered either by recapturing the fish or, in the case of pop-off satellite

tags, by automatically releasing the tag from the fish and then transmitting the data via a satellite to a receiving station.

Both types of tags will be used in the proposed programmes to track emigrating post-smolts and returning adult salmon. The following two sections provide an outline of the approaches that will be used and the associated costs. It is difficult to provide precise estimates of costs for conducting a large scale telemetry programme at this point. The study is likely to be made up of a number of smaller-scale studies the costs of which will depend on local conditions and requirements. One of the main objectives of the programme will be to facilitate collaboration between such projects to allow the use of shared detector arrays and other facilities, thus reducing costs to each study. In addition, costs of tags and receivers may decrease if they are bought in bulk, and in the longer term prices may be expected to decrease as technological capabilities increase.

5. POST-SMOLT TRACKING

5.1 Approach

Post-smolts will be studied during the first phase of the marine migration by tagging emigrating smolts with acoustic transmitters, as described for the studies undertaken in a number of North American rivers (e.g. Kocik et al., 2009). Fish will be caught in NAC and NEAC rivers that have existing trapping facilities (e.g. 'index rivers' (ICES, 2013)) and will be tagged with acoustic transmitters (see equipment details below). The additional costs associated with releasing acoustically tagged fish should therefore be relatively small.

Acoustic receivers will be deployed in freshwater (e.g. above head of tide), in the estuary and in coastal waters to cover potential migration pathways. For example, in the NAC studies, lines of receivers have been deployed within selected riverine, estuarine and near-shore environments for certain index rivers emptying into the Gulf of Maine (Figure 5.1.1) and the Gulf of St. Lawrence, including lines of receivers across the Cabot Strait and Strait of Belle Isle (Figure 5.1.2). Opportunistic deployments of receivers have also occurred throughout the Gulf of Maine, and there is an array extending from Halifax, Nova Scotia onto the Scotian Shelf (Figure 5.1.3). While similar large arrays have not yet been deployed in the NEAC area, individual receivers and smaller arrays have been used, and there is interest in extending these studies in a number of areas.

The choice of release sites and the positioning of detection arrays will take into account new knowledge from the SALSEA programme on the migration and distribution of post-smolts in the southern NEAC area and for Gulf of St. Lawrence and US rivers in NAC area. Longer arrays of receivers are likely to be required the further the fish are detected from their home rivers, but ideally it will be possible to establish them at identified choke points along the near-shore migration paths of post-smolts. Alternative options will also be investigated for deploying receivers further offshore, including the possible mounting of receivers on observation platforms, drifting buoys and autonomous vehicles.

Further development of technologies for monitoring acoustically tagged salmon at sea will evaluate the use of wave gliders as presently being developed by the Ocean Tracking Network (OTN) (http://oceantrackingnetwork.org/, Dalhousie University, Canada; see Sec 9.2) as well as potential opportunities for developing receiver capacity on broad-scale oceanographic projects such as the ARGOS program (http://www.argo.ucsd.edu/index.html) and the Global Ocean Observing System (GOOS) (http://gosic.org/goos). The possibilities will be investigated for increasing the detection of acoustically tagged post-smolts in both near-shore and offshore areas by deploying receivers during existing national marine biological and oceanographic monitoring programmes or at fixed monitoring stations (e.g. remote sampling buoys).

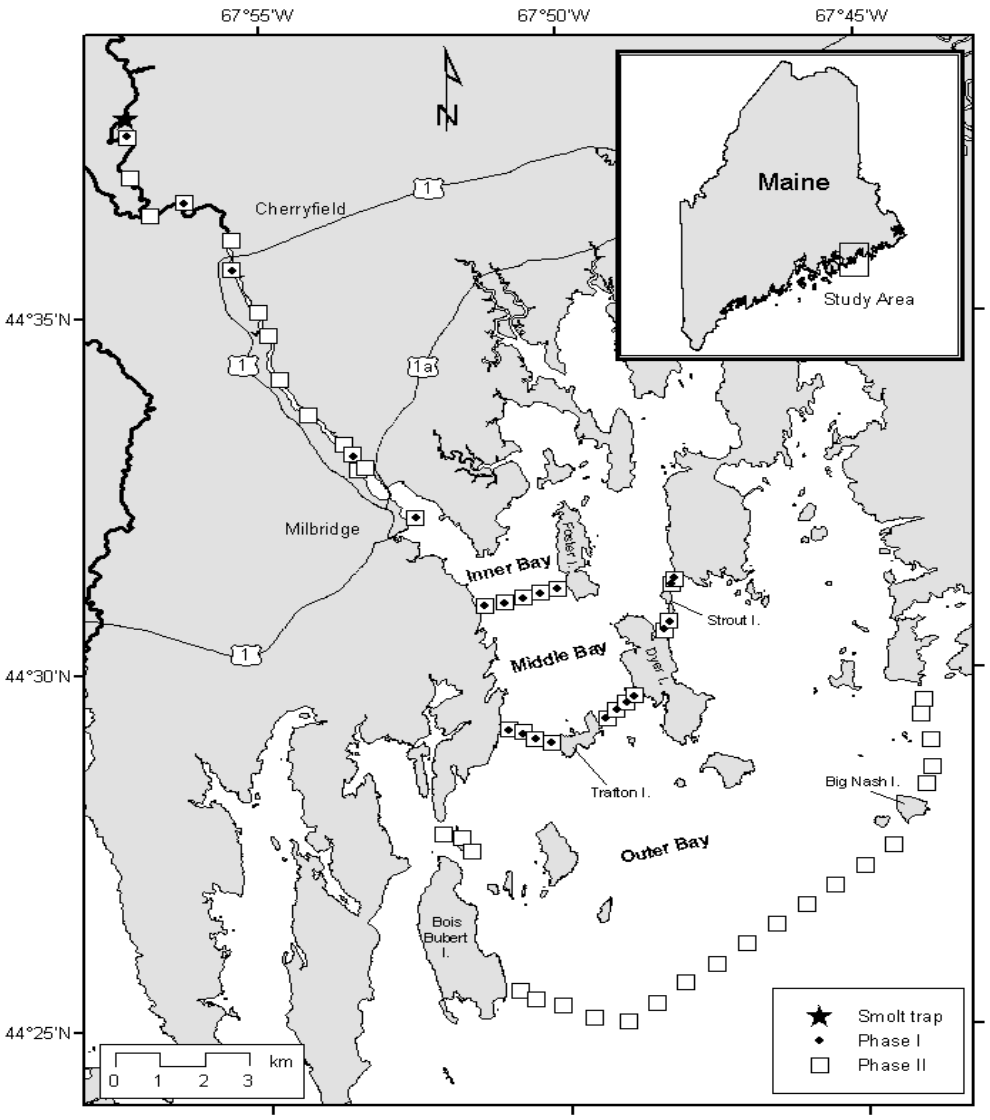

Figure 5.1.1. *Study area in Narraguagus River and Bay, Maine illustrating location of rotary screw trapping and release site as well as locations of acoustic receivers during Phase I (1997-1999) and Phase II (2002-2004). Inset indicates extent of study area and Narraguagus Watershed. [From: Kocik et al. 2009]*

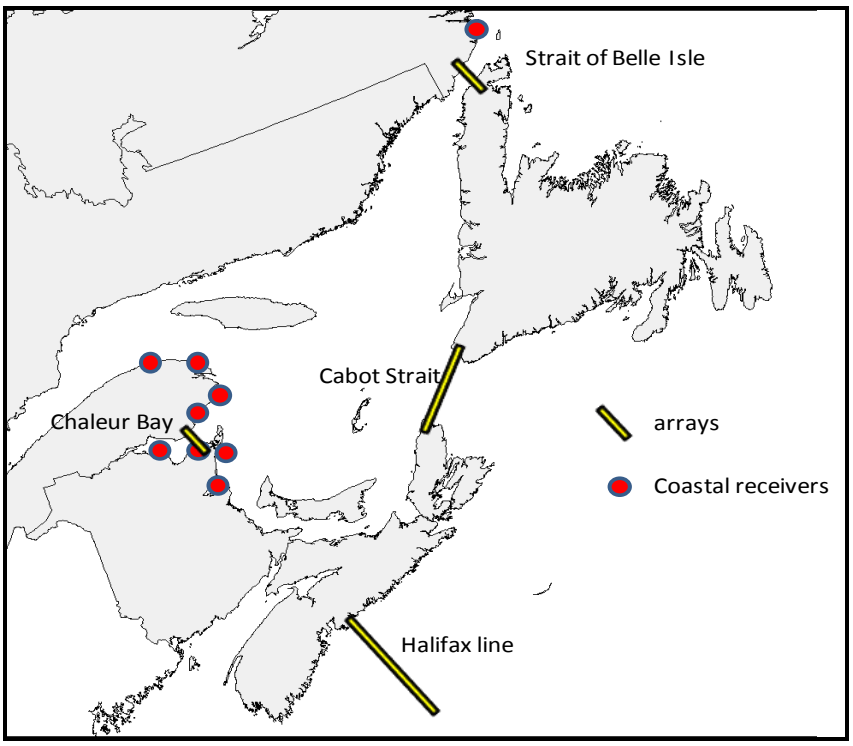

Figure 5.1.2. *Summary of coastal receives deployments and arrays on the east coast of Canada. Other receivers are deployed for numerous other studies focused on marine species.*

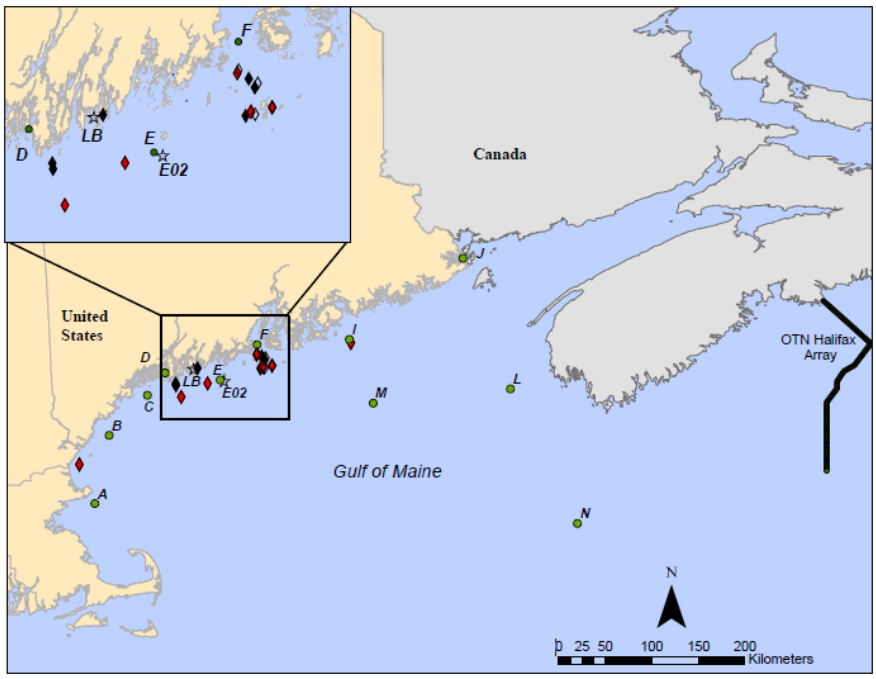

Figure 5.1.3*. Locations of collaborative deployments of receivers to monitor ultrasonically tagged marine animals within the Gulf of Maine, US. IOOS buoys (National Oceanic and Atmospheric Administration's Integrated Ocean Observing buoys System) are indicated by green circles; diamonds are the location of tMOLT receivers (i.e. commercial fishing gear; black 2010, red 2011, open 2012); and open stars represent private weather stations. Oceanographic drifters, with receivers attached, were released and drifted throughout the Gulf of Maine, but are not shown here. [From Goulette et al. accepted]*

5.2 Equipment and costs

5.2.1 Acoustic transmitters

Acoustic transmitters (i.e. tags) will be attached externally or by surgical implantation in the peritoneal cavity of emigrating smolts. The size of the fish will therefore limit the size of the tag, and this will affect the choice of frequency and the batteries life of the tag. The normal operating frequencies for tags used on smolts are around 69-76 or 180-200kHz. Although higher frequency tags are smaller, they have shorter transmission range, and tags with fewer/smaller batteries will generally have a shorter operational life.

The acoustic tags will be coded, providing over 80,000 unique ID's on a single acoustic frequency and allowing individual animals to be recognized from a single transmitted pulse. This allows large numbers of individuals to be tracked simultaneously and tag life to be extended (e.g. by operating tags at lower pulse rates). In addition to simply indicating their location, certain tags can also transmit environmental (e.g. water temperature, depth) or physiological (e.g. heart rate) data.

Currently all North American tracking of Atlantic salmon post-smolts in the Northwest Atlantic utilizes VEMCO V9 coded tags. Standard transmission range is up to 800 meters, depending on environmental conditions. The expected transmission life is ~3 months, but the tags may be turned on and off at specified times to extend the active life of the tag. For example, a tag deployed on an emigrating smolt may be turned on for the freshwater/near-shore portion of the migration, shut off for a few weeks/months and then turned back on during a specific period of the oceanic migration. As researchers gain increased understanding of the marine migration of Atlantic salmon through studies such as these, more detailed and refined study plans can be developed to maximize the output from the expended resources.

At the initiation of any telemetry monitoring program, it is difficult to advise on the number of tags that should be released to achieve a target level of precision for estimates of survival/mortality. To determine the number of tags needed, information on the survivorship and detection efficiency probabilities between monitoring sites is needed. As projects progress and data are accumulated, researchers can use the results to refine their study design and adjust the number of tags released to accomplish a targeted level of precision.

Acoustic transmitters suitable for use of smolts currently cost about £200-270 per tag. Initially, the number of tags released is likely to be of the order of 100 tags per site per year: cost ~£27,000 per site per year.

5.2.2 Acoustic receivers and arrays

A range of receiver systems will be required to address local conditions and requirements.

Manual tracking receivers are designed for mobile tracking of one or more transmitters and allow real time direction finding or 2D/3D positioning from a moving vessel; they may be held manually or fixed to the vessel. The approx cost of a single frequency manual tracking receiver is ~£6,000

Fixed data-logging receivers operate passively, recording the time and code for any tag signal detected. They may be suspended in the water column or mounted on the sea bed. In most locations, receivers will require moorings that may include weights, trawl protectors and surface marker buoys. Modern receivers can be downloaded remotely to a vessel passing nearby (e.g. through an acoustic link) allowing them to be deployed for months or years without being brought to the surface, however, fouling by weed and crustacea may be a problem in some locations. The downloading equipment is now being integrated within Remotely Operated Vehicles (ROV), which is expected to further reduce the cost of recovering the data.

Approx costs of:

- Singe frequency standard underwater receiver (~ 15 months battery life): ~ £1,200
- Dual frequency (69 kHz + 180 kHz) long-life receiver (~3yr battery life): ~£10,000
- Trawl resistant float collar for long-life receiver ~£2,100

- Other mooring costs ~£2,500 per receiver

Deployment costs for acoustic receivers will be very site specific, however it may be expected that up to 10 receivers may need to be deployed around the estuary of the river into which tagged smolts are released.

The size of coastal receiver arrays will depend on the local topography and the mooring will depend upon local conditions and fishing activities.

- Total cost of a 10 receiver coastal array requiring annual servicing ~£60,000
- Total cost of a 10 receiver coastal array requiring 3 yearly servicing ~£150,000

Vessel time will be required to deploy, service and collect data from receivers as well as for active manual tracking. Charter costs may vary between less than £1,000 to more than £10,000 per day depending upon vessel size and capability. The specific requirements will be dependent on the types of receivers used, local conditions, etc.

- Approx cost to deploy or service (i.e. recover and re-deploy) 10 buoys: £2,000-£50,000.

  (Costs will depend on the system being used, the number of receivers, the location, and the size of vessel that is required.)

5.2.3 Additional detection systems

In addition to identifying fixed locations where receivers will be deployed, opportunistic deployments of detection systems by all potential collaborators should be investigated. Goulette *et al.* (2014) demonstrated how opportunistic deployments of receivers with a variety of collaborators can provide large amounts of additional data for many different telemetry studies occurring within a general area. In the Gulf of Maine (US) salmon researchers coordinated the deployment of receivers on commercial fishing gear (lobster pots), oceanographic monitoring buoys (IOOS receivers) and drifters and private weather stations (see Section 5.1 and Figure 5.1.3). Deployment costs were minimal as no additional mooring equipment was required, minimal mounting equipment was needed and collaborators provided the personnel to deploy the units during routine maintenance events. As a result, a total of 17 different groups/organizations/agencies received detection data (approximately 13,000 detections of nine species over eight years) for their released animals from these NOAA opportunistic receiver deployments.

A range of systems might be also used to detect acoustically tagged salmon further offshore. For example, receivers could be mounted on autonomous vehicles which could then be programmed to patrol likely migration routes. OTN has deployed Slocum electric gliders (OTN200 and OTN201) and a Liquid Robotics wave glider along the receiver lines off Halifax (Canada). OTN's Wave Glider was purchased primarily to upload data from bottom-mounted acoustic receivers that detect tagged marine animals as they pass by. After uploading the data via an acoustic modem, the Wave Glider transmits the data back to OTN over the Iridium satellite network. As the Wave Glider is equipped with a VEMCO VR2C hydrophone, it can also act as a mobile receiver for any tags in the vicinity. While performing these duties the onboard meteorological, physical and biogeochemical sensors collect data and transmit them every 10 minutes for near real time observing of the ocean. These new technologies provide opportunities for long distance retrieval of data from offshore receivers and tracking movements of tagged animals.

Receivers might also be mounted on research vessels or opportunistically deployed over the side of the vessel or attached to oceanographic platforms during oceanographic profiling. The number of stations which are occupied during national research vessel activities of all types are in the thousands annually and are dispersed over wide geographic areas in the North Atlantic.

6. ADULT SALMON TRACKING

6.1 Approach

Similar technologies and year-round detection arrays could be used to estimate mortality of salmon captured, tagged and released in oceanic feeding areas as are proposed for post-smolts. However, some such studies would depend on the use of the novel open ocean detection systems as outlined above and would present greater logistical problems. For example, it may be costly to tag sufficient numbers of fish to provide quantitative estimates of mortality during different phases of the return migrations to different regions.

As a result, two different technologies could be used to collect information on the migration and mortality of adult salmon at sea. Continued pop-up satellite tagging (see equipment) of Atlantic salmon at West Greenland (ICES 2013) will collect additional data on migration routes of the fish and provide extensive data on their behaviour at sea. In addition, considering that a very high proportion of the fish currently captured at West Greenland originate from rivers emptying into the Gulf of St. Lawrence and that there is a significant telemetry monitoring infrastructure within the Gulf region, fish captured during satellite tagging programmes, but not selected for satellite tagging, could be tagged and released with ultrasonic telemetry transmitters. Depending on the survival rate, there could be a significant chance of collecting some information from these ultrasonically tagged fish as they re-enter the Gulf region. Limits on sample size may make it difficult to obtain precise estimates of mortality, however the qualitative information would be novel and extremely informative to future tagging efforts targeting salmon at Greenland. Given the existence of appropriate capture infrastructure, these same approaches could be applied to salmon captured in the Northeast Atlantic.

Effort should also be put into evaluating the scope for capturing and tagging adult fish on their return migration through coastal waters, capitalizing on the receiver infrastructure used to track emigrating post-smolts in NAC and NEAC coastal waters, to quantify the mortality during the return migration.

6.2 Equipment and costs

6.2.1 Acoustic transmitters and receivers

Tags used on adult fish can use larger transducers (lower frequencies) and more batteries, thus providing greater tag range (up to 1km) and longer operational life (> 1.5 years). Tags used on adult salmon generally operate at frequencies around 70kHz. The cost of these transmitters is similar to that for post-smolts, ~£270 per tag. The number of tags released is likely to be constrained by problems of catching sufficient fish in good condition, but might initially be of the order of 25 tags per study/site per year: cost ~£6,750 per study/site per year.

The receiver systems would be similar to those described for post-smolts. However, detection arrays might also be deployed off the coast of West Greenland and could provide data on localized fjord movements of salmon during summer feeding periods for both NAC and NEAC origin salmon. These arrays would be able to collect data on fish captured, tagged and released at Greenland as well as post-smolts released in home waters as long as the tags have been programmed to operate during this period of the marine migration. Additional detections of tagged salmon off the coast of Greenland and through the Labrador Sea via receivers deployed on oceanographic monitoring equipment, drifting receivers, autonomous vehicles and other systems will provide additional data to be used to estimate stage-specific mortality. Detection equipment deployed in home waters would also have the potential to detect adult salmon returning to natal rivers to spawn as long as the tags are transmitting.

6.2.2 Archival and satellite tag:

While archival and satellite tags are not directly applicable to the proposed acoustic telemetry programmes, they may provide a useful supplement to these studies in areas where acoustic tracking proves difficult. Both archival and satellite tags have been used on salmon tagged in the open ocean and kelts emigrating from rivers.

Archival tags do not transit a signal but record the time, and environmental (e.g. temp, depth light, etc) and/or physiological data at regular intervals. These data can only be downloaded if the tag is recovered; this normally requires the fish to be recaptured, although some studies have employed floating tags which may be found when they wash up onto beaches after the fish dies. The

environmental data collected by this means can be used to reconstruct the migration route of the fish, e.g. using light based location algorithms. The data may also provide information on the fate of the fish; for example, fish eaten by marine mammals record an increase in temperature as the tag passes through the predator. Archival tags are small enough to be used on large smolts and can store large amounts of data. The smallest archival tags weigh about 1 g in water and currently cost ~ £350 each.

Pop-off satellite tags use Platform Transmitter Terminals (PTTs) that communicate via radio-signals to orbiting satellites. Conventional satellite telemetry makes use of the widely used Argos or Iridium satellite receiver systems which localize the signal and provide positional fixes (latitude and longitude) for the transmission. However, as radio signals are attenuated in salt water, the tag must be on the surface for the signal to be detected. As a result, when used on fish, satellite transmitters are usually incorporated into a pop-off mechanism which releases the tags after a predetermined period. The tag then transmits any environmental or physiological data collected during the track which can be used to describe the behaviour and migration of the fish (similar to an archival tag). Pop-off satellite tags are currently much too large to be deployed on smolts or post-smolts but can be attached to 1SW salmon. Satellite tags currently cost ~£2,300 each.

7. DATA AND ANALYSIS

7.1 Database Infrastructure

It is likely that large scale telemetry research efforts will begin with small scale pilot studies to establish and fine-tune the experimental approach and demonstrate the value of the results. However, it is important that there is optimal coordination in data handling and information recording from the outset. For example, if a number of telemetry programmes are being undertaken in parallel, it is essential that any research group can identify any tags detected on their receivers and that the detection of tags from other studies is reported to the appropriate researchers. Similarly, the location of all receivers must be recorded centrally and the information made available to all research groups to ensure that researchers can plan new receiver deployments effectively. In addition, knowing that fish are not detected in other areas where there are monitoring programs underway, will provide valuable supplementary information which can be as informative as data from actual detections.

To maximize the benefit gained from the resources expended, any large scale telemetry project should involve easy to use and accessible databases identifying:

- all the tags that have been released;
- the location of all receiver units;
- summaries of all tags detected by each receiver

The utility of this effort will be greatly increased with a significant outreach campaign to disseminate information on each research programme and to indentify the potential for collaboration. An example of the type of collaboration envisaged for this program is from the Oceans Tracking Network which makes the oceanographic and marine animal tracking information collected via their network freely accessible. The data adheres to the intellectual property rights of the providers and is subject to quality control standards. OTN data managers are developing a self-sustaining data warehouse system as well as new and innovative tools for synthesis, analysis, and visualization of the different types of data collected by Canadian and international researchers using OTN's global acoustic infrastructure.

7.2 Modeling methods

Survival and detection probabilities can be modelled using established methods (e.g. Cormack-Jolly-Seber (CJS) release-recapture model (Seber 1982)). There is also a widely used software application (MARK) available for the analysis of data from marked individuals, which is a very flexible and powerful program that encompasses virtually all currently used methods for analysis of marked individuals. Program MARK has become a standard tool for the analysis of these types of datasets, partially due to its flexibility, track record and availability. It is freely available (http://www.phidot.org/software/mark/) and has been coded within the R language (RMark).

Gimenez et al. (2007) and Royle (2008) have also described a Bayesian state-space model variant of the CJS model. Typical analysis explores two different modelling approaches: the full CJS model,

where both survival and detection probabilities are site-dependent for each group and a model where group survival is independent but detection probabilities are pooled at each site.

However users are not limited to these two approaches, and many researchers around the globe have garnered a significant amount of expertise with modelling these data types, thereby increasing the utility of the data collected and analyzed. A special Theme Session on analytical approaches for handling tracking data will take place at the 2014 ICES Annual Science Conference.

8. INTEGRATION OF CURRENT AND PROPOSED TRACKING PROJECTS

The proposed programmes will involve tracking the movements of emigrating smolts and returning adult salmon through the waters of multiple states. These studies will present different challenges but optimal operation in coastal and open ocean waters will require close coordination on the use of equipment, the tagging activities and the operation of detector arrays over large geographic areas.

The programme will make best use of the fish capture facilitates on existing index rivers in the NAC and NEAC areas (Annex 1), and these will be evaluated as the first choices for release of acoustically tagged smolts. Tagging and release of smolts is expected to be organised by national agencies, but will need to be co-ordinated in space and time to make optimal use of shared detector arrays. The equipment used by all groups must be compatible to ensure that all fish are uniquely marked and can be detected and identified by all research groups. The deployment of receivers in and around estuaries is also expected to be coordinated by national agencies.

To get the best value out from the deployment of coastal receivers, offshore detection systems and mobile tracking, it will be essential to develop links with research groups working on other migratory species such as eel, sea trout, sharks and marine mammals. Many federal and state agencies, universities and regional NGO groups are engaged in localized studies investigating the ecology and migration of a variety of marine species (e.g. crustacea, fishes and mammals) in estuaries and coastal waters. Such studies can create regional networks of arrays which, if properly coordinated, will greatly enhance each individual study. Outreach, collaboration and coordination with these groups will be pursued to the greatest extent possible.

The development of open ocean detection systems will depend upon international collaboration given the very large spatial extent of the study area (i.e. North Atlantic Ocean, Norwegian Sea and Arctic Ocean), the inclusion of multiple Exclusive Economic Zones (EEZs) and the significant costs associated with such an effort. It is hoped that by sharing costs between a number of such groups it will be possible to develop more comprehensive detection systems.

8.1 Current and proposed tracking initiatives in the NEAC area

8.1.1 Estuary and near-shore tracking:

Within Europe there has been relatively little tracking of post-smolts beyond the immediately vicinity of estuaries or fjords, but there are a number of initiatives planned which could involve the release of acoustically tagged animals and the deployment of coastal detector arrays (Figure 8.1.1.1).

Ireland: Initiatives are under way to place acoustic arrays off the south east coast of Ireland around Wexford and Cork to track marine fish species (notably sea bass). This is an important location for salmon migrating from the Suir, Nore and Barrow and Cork Blackwater which support substantial populations of wild salmon. It is also a key area for sea trout and sea trout are known to migrate between UK and Ireland.

Scotland: A research programme is underway to investigate the coastal movements of migratory salmonids in relation to potential renewable energy sites (e.g. wind farms). This programme will deploy acoustic detector arrays around the coast of Scotland. There are also a number of proposals for smaller scale studies of the coastal movements of sea trout. There is potential interest in the movement of species such as basking shark on the west coast of Scotland.

Northern Ireland: There are plans to create an array off the mouth of the Foyle River to investigate possible effects of wind farming on salmon migrations. A collaboration with AFBINI in the River Bush could see arrays on the Antrim coast and or across the channel between Northern Ireland and Scotland (approx. 25 km.)

Denmark: Tracking has been used to investigate the behaviour and movements of salmon smolts and to investigate levels of predation.

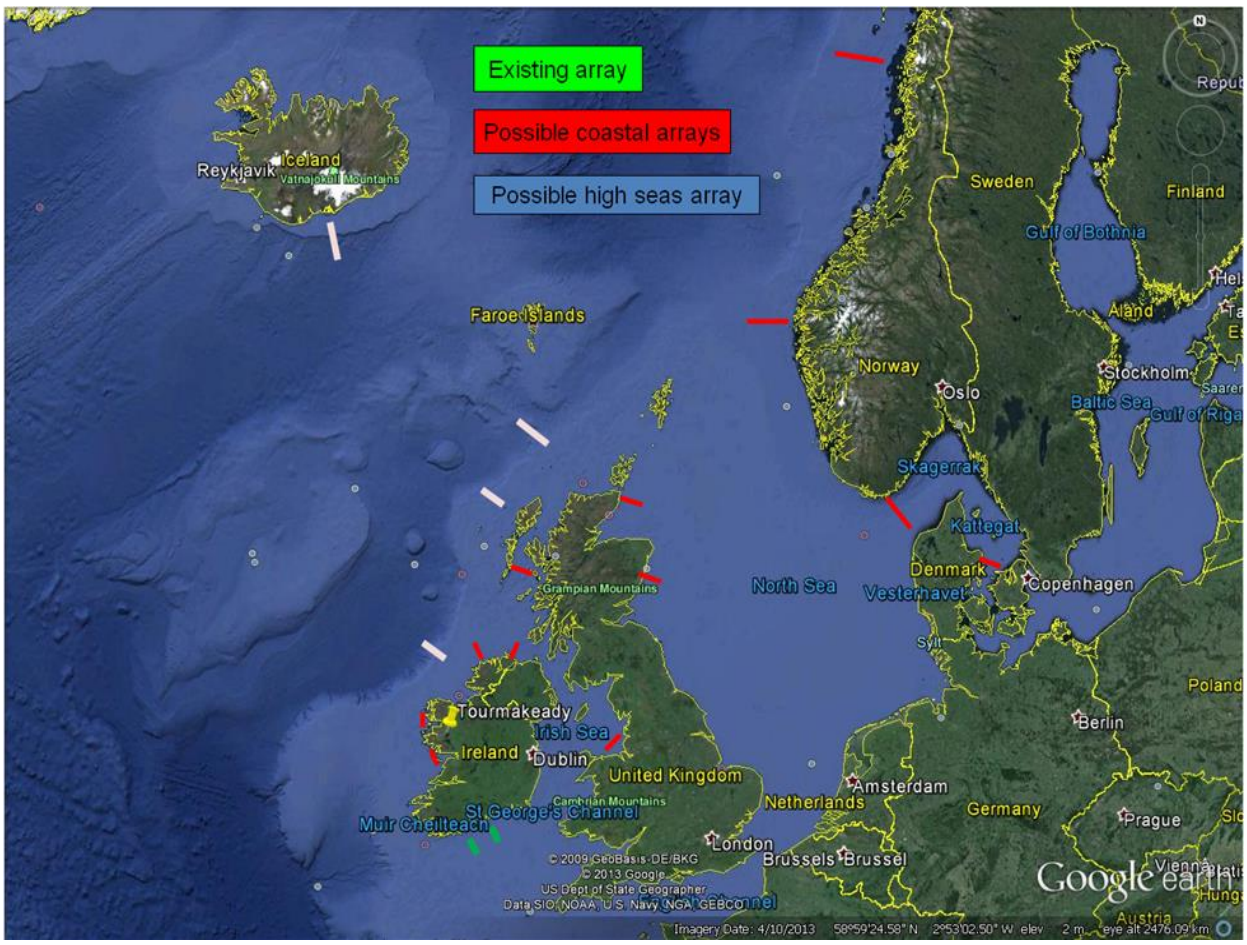

Figure 8.1.1.1. *Possible locations of collaborative deployments of receivers to monitor ultrasonically tagged fish and or marine animals in NEAC coastal waters and the shelf edge.*

Russian Federation: There are possible plans to undertake mobile near-shore tracking of salmon smolts and adult fish.

8.1.2 Coastal and offshore arrays:

There are currently no firm plans to deploy longer coastal arrays of acoustic receivers in the NEAC area. Surveys conducted during the SALSEA programme indicated that shelf edge is the principal route along which smolts from Southern Ireland, Spain, France and probably Southern England/Wales migrate to feeding grounds in the Norwegian Sea, and it is probable that they make use of the shelf edge current to aid their northward migration. This current passes very close to the west/north west of Ireland (approximately 50-70km from the coast to the 200m isobath). The 150-200m isobath separates coastal and oceanic waters, shelving steeply from the 200m isobath to the 1000 isobath in about 20-30km. It also passes in relatively close proximity to the Western Isles off NW Scotland.

8.1.3 Offshore detection systems:

Once the post-smolts move further offshore they are believed to become more widely dispersed, although the SALSEA project provided some indication of general migration routes. The use of detector arrays, drifting receivers, autonomous vehicles and other systems in such areas is largely untested. There may be other areas where the migration routes of salmon are relatively restricted (e.g. Faroes-Shetland channel). These are the types of areas where the use of these technologies will be considered.

8.2 Current and proposed tracking initiatives in the NAC area

8.2.1 Estuary and near-shore tracking:

Within North America, there are a large number of ongoing tracking studies from the Gulf of Maine up through Newfoundland and the Gulf of St. Lawrence involving Atlantic salmon and a number of other marine species. A well established network of riverine, estuarine and coastal arrays currently exists. These receiver arrays will be maintained and targeted smolt releases will occur into the future, as budgets allow. The objectives of these releases are to monitor the migration dynamics and survival of emigrating Atlantic salmon smolts and post-smolts and potentially competitors of salmon including striped bass.

In the US, monitoring of Penobscot River smolt and post-smolt migration has occurred annually since 2005 and is expected to continue in the near future. Trapping and monitoring of smolt migration on a number of other rivers is expected to continue into the future and provides an opportunity for expanded telemetry monitoring. In additional, new projects are being proposed for a number of different river systems (e.g. Kennebec River) that if approved will be coordinated with other North American tracking efforts and could be included in a large North Atlantic-wide effort. There is ample opportunity for expanded releases of tagged migrating US Atlantic salmon smolts to contribute to a large international telemetry monitoring program.

8.2.2 Coastal and offshore arrays:

In May 2012, the OTN completed the deployment of 256 receiver stations extending 205 km southward onto the Scotian Shelf from Halifax, Canada (OTN Winter 2013 Newsletter). In October 2011, the Cabot Strait Line with 151 receiver stations spanning 100 km from Cape Breton (Nova Scotia) to Newfoundland was also fully deployed. Detections of acoustically tagged animals on these lines included Atlantic salmon, Atlantic cod, Atlantic Bluefin tuna, and grey seals. Finally, a third line was deployed in collaboration between OTN and the Atlantic Salmon Federation across the Strait of Belle Isle between the northern tip of Newfoundland and southern Labrador. This line and the Cabot Straight line effectively monitor the two entry and exit routes for aquatic animals into the Gulf of St. Lawrence. These arrays have the capacity to monitor passage of Atlantic salmon from the US, and all areas of eastern Canada.

Detection data collected along the OTN Halifax receiver array has demonstrated that southern NAC post-smolts appear to migrate north along the Scotian Shelf in close proximity to the shoreline. Additionally, mortality appears to be relatively high in the immediate estuarine and nearshore areas and much lower as post-smolts enter the open ocean (i.e. Gulf of Maine and Gulf of St. Lawrence). To gain further information on the early marine migration of these southerly NAC populations en route to the Labrador Sea, consideration could be given to deploying a new coastal array off of the southeastern Newfoundland coast onto the Grand Banks in a similar fashion to the OTN Halifax array. This array would also be capable of monitoring any other life stage of salmon using the Grand Banks area.

There is currently a collaborative effort among US, Canadian and NGO interests to coordinate the deployment of a coastal array to monitor entrance to and exit from the Bay of Fundy. This array would use geographic choke points (i.e. Grand Manan Island) to monitor the use of the Bay of Fundy by both US and Bay of Fundy stocks, which are listed under respective federal protective legislation. Similar detection arrays were deployed in this area (Lacroix 2012) during 1995 and 1996 and provided novel migration data for both of these stock complexes. Based on the knowledge gained during that effort and the technological advance made with tags and receivers, a modern day effort would have a high expectation of success. Additional support and coordination for this effort could improve the likelihood of it being implemented.

8.2.3 Offshore detection systems:

Once the post-smolts move further offshore they are believed to become more widely dispersed, and the historical survey data indicate that they are widely distributed across the southern Labrador Sea. Non-maturing adult salmon are also known to congregate around summer feeding grounds off the coast of Greenland from early summer through late fall.

A range of systems is being considered to detect acoustically tagged salmon further offshore. Receivers could be mounted on autonomous vehicles which could then be programmed to patrol likely migration routes. The OTN has deployed electric and wave gliders to upload data from bottom-mounted acoustic receivers and search for detect tagged marine animals (see Sec 5.2.3). Receivers

have also been deployed on buoys of opportunity in the Gulf of St. Lawrence and Atlantic salmon, Bluefin tuna and American eel were detected on these systems ((OTN Winter 2013 Newsletter).

9. FUNDING AND STRATEGIC PARTNERS

9.1 Funding

Funding is expected to be obtained from both local/national and international sources. Studies of smolt movements in coastal water are expected to be part funded within national programmes. The establishment of coordinated networks of receivers and the deployment of novel offshore receiver systems are expected to require international collaboration and funding from sources such as the EU Framework programme. Funding partnerships with Marine Research Foundations (primarily in North America e.g. Pew Charitable Trusts, the Ocean Foundation), private sector conservation bodies and NGO organisations associated with NASCO, may also be a possibility. Such bodies have extensive experience of fundraising for ocean based environmental projects and their experience and expertise could prove very useful in seeking support for components of the programme. Funds could also be sought from industry (e.g. energy companies), and this could be facilitated through the IASRB. The Ocean Tracking Network would also be a key strategic partner in seeking and obtaining funding for such and effort.

Funding will also be sought through collaboration with scientists and managers working with other species such as marine mammals and sharks, and this could be greatly facilitated through IASRB engagement.

9.2 Research organisations

Coordination between government and university research groups may be assisted by NGO groups (e.g. the Atlantic Salmon Federation has operated and maintained a number of the receiver arrays in estuaries and coastal waters in the Gulf of St. Lawrence and undertaken acoustic tagging of smolts and kelts, and the Mirimichi Salmon Association has assisted with kelt tagging studies) and international research groups such as the OTN and Integrated Ocean Observing System (IOOS), which already have links with groups working on a wide range of projects.OTN is a 7-year Network program funded by the Natural Sciences and Engineering Research Council (NSERC) of Canada, beginning in January 2010. This Network represents the research hub for a range of projects that make use of new and innovative technologies across Canada's Atlantic, Arctic, and Pacific Ocean "Arenas" to better understand continental shelf and ocean ecosystems (Figure 9.2.1).

OTN Canada is a partnership primarily between university researchers and the Department of Fisheries and Oceans (DFO) Canada, but also draws upon collaboration with scientists and managers from other federal and provincial departments, conservation agencies, industrial collaborators and international researchers. The principal objective of OTN Canada is to better understand changing ocean dynamics and their impact on ocean ecosystems, animal ecology, and ocean resources, with the aim to address critical issues in resource management and implications for ocean governance. OTN has indicated that it may be able to assist with the design of the proposed programme and with funding the deployment of arrays.

The US Integrated Ocean Observing System (IOOS) is a national-regional partnership overseeing a national ocean observing network. The US IOOS is currently undertaking efforts to enhance the ability to collect, deliver, and use ocean information, including biological information, such as that collected from electronic tags attached to marine animals. There is currently a proposal within IOOS to create an Animal Tracking Network (ATN) to oversee the development and implementation of a large scale animal ocean observation system within US marine waters. IOOS/ATN would be a potential strategic partner within the US that could help facilitate the implementation of a large scale tracking program within the North Atlantic.

In the southern part of the NEAC area, local partnerships are either in place or the opportunities for such partnerships are currently being investigated. For example, SmartBay Ireland is responsible for the establishment and development of a National Research, Test and Demonstration facility to support the application and translation of research and provide platforms for the testing and demonstration of new technologies and solutions in the Marine and related sectors.

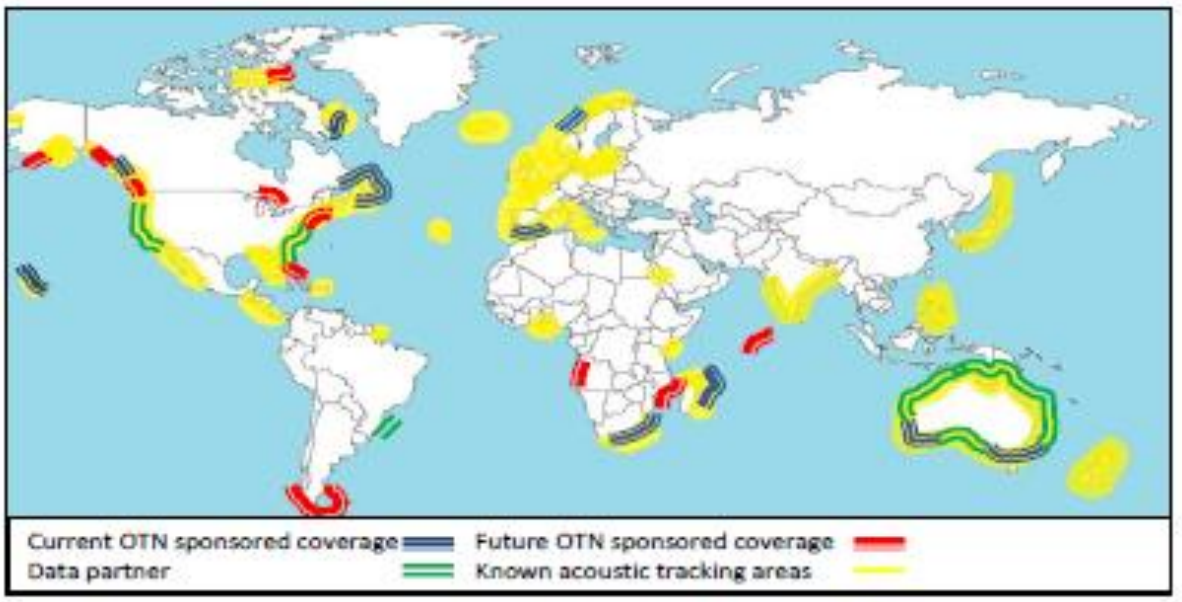

Figure 9.2.1 Summary figure of Oceans Tracking Network of current and future deployments in the Atlantic Ocean and elsewhere. Reference: OTN Winter 2013 Newsletter.

9.3 Equipment manufacturers

There are relatively few companies making tags and/or receivers that would be applicable to this study, and equipment made by different companies is not always compatible. While it is recognized that some research funders will require open competition between potential equipment suppliers, it is essential that all participants in the study use compatible equipment to obtain the best value from the programme. The principal requirements are that all receivers must be able to detect all tags and that all tags must be uniquely identifiable. There will therefore be a need to either select a single supplier for the whole programme or to seek agreement on the development of compatible equipment by multiple suppliers. Use of a single tag supplier will ensure optimal compatibility between all parts of the tracking system and that all tag codes can be uniquely identified.

There are a number of physical constraints and limitations on the equipment that can be used for tracking salmon at sea, and these will need to be taken into account in designing a large international programme. Where possible, pooling resources to place fewer and larger orders will help reduce costs.

Ancillary equipment is also required for the study such as moorings for receivers, acoustic release mechanisms for recovering bed mounted receivers, etc. Coordination between groups will assist in minimizing costs of development and purchase of such equipment.

Opportunities for obtaining support from other industrial partners, such as marine renewables, who will benefit from the results should also be explored.

Use of national research vessel surveys from multiple countries requires central coordination to deploy receiver units and monitoring and to coordinate data sharing and security.

10. RISKS AND LIMITATIONS OF RESEARCH ACTIVITY

10.1 Funding

- The equipment and infrastructure for this telemetry programmes is expensive with major initial capital investments (receivers) and significant annual costs on expendable items (acoustic tags).
- The project will depend upon multiple national and international funding streams that will need to be co-ordinated in time and space.

- Similarly, the proposed use of near-shore and offshore platforms to establish telemetry stations will require a high degree of co-ordination and cooperation with operators. For example, shared use of receiver arrays requires that the studies operate simultaneously or that arrays deployed for one study are left in place for another study. Developing partnerships with marine industries will be critical in this regard.

10.2 Study areas

- The optimal location for initial studies will depend on a range of potentially conflicting factors, including the most suitable geographical features for establishing detector arrays (e.g. migration choke points); the areas where other species may be tracked; the countries providing funding; opportunistic opportunities for receiver deployment, etc.
- This will affect the choice of locations for detector arrays. However, there is a lot of information to guide the choice of areas where the deployment of equipment could be optimised to provide good coverage of actively migrating salmon.

10.3 Coordination

- The project will ideally involve the coordinated release of tagged smolts which will depend upon collaboration and co-ordination between research agencies in different countries. Such coordination may depend on the objectives of different groups. However, a high degree of data sharing has been in place for conventional salmon tagging programmes for many years and a compilation of all salmon tagging activities in the North Atlantic has been provided annually by parties to NASCO. The SALSEA Programme was predicated on this approach and the co-ordination of a wide range of laboratories and research centres was successfully achieved over a four year period.
- Co-ordination is also required in the deployment of detector arrays in a number of different locations. This may be challenging if different components of the programme are funded in different ways. A key factor will be the ability to maintain the telemetry infrastructure under demanding conditions.
- Detector arrays will be very expensive to set up but should have more modest on-going costs. However, maintaining funding for arrays after the completion of specific projects will be a key objective to ensure continued use of the systems which are put in place, thus saving on costs for future projects.

10.4 Equipment

- Supply of all equipment by a single manufacturer may present problems for some funding agencies. Development of compatible equipment may be resisted by manufacturers or result in less reliable equipment. The challenge for equipment manufactures may be in collaborating with each other to provide the most comprehensive suite of electronic equipment to cover the wide ranging marine areas and conditions likely to be experienced.
- The operational life of acoustic tags that are small enough to be deployed on smolts is limited to 2-3 months, although tags can be programmed for delayed transmission and advancements in technologies are ongoing. This may require separate batches of tags to be released to investigate different periods of the early marine migration.
- The tags ideally need to be applied to larger than average smolts (e.g. >= 14 cm fork length) and so the results will need to be cross-checked with other information from conventional tagging returns, post-smolts surveys or migrational models.
- The detection efficiency of detector arrays will be site specific and may be difficult to predict. Detection efficiency may also change over time due to varying marine conditions and fouling of the receiver. These factors will be taken into account in the experimental design, any initial range testing and setting up of equipment and subsequent analyses of results
- It may be impractical to deploy receivers in some locations and alternative methods of receiving information (e.g. active tracking in research vessels) may be required.

- Such programs have not been attempted in open ocean areas not associated with land borders and detection systems may need to be developed and tested for use in these areas.
- Detection efforts (cumulative days) during the varied marine research vessel surveys may be insufficient to detect a statistically efficient number of the surviving acoustically tagged salmon post-smolts in the large expanses of the Norwegion Sea / Irminger Sea. However, the cost of such an exercise can be low as it does not require any extra vessel time and there is good information on CPUE from post-smolt trawls at sea to be able to initially identify key areas of the migration.
- Mobile near-shore tracking from a moving platform can be effective in restricted areas of fjords, bays and straits where detector arrays cannot be used for different reasons.

11. NEXT STEPS

This report provides only a rough outline of the proposed large-scale international collaborative research programme. The details of the programme will depend upon a large number of factors including the willingness of research agencies and their ability to participate, the funding that is made available, the requirements of the funding agencies and a large number of logistical issues.

While it is not anticipated that the IASRB will be able to provide significant funding, at least with current resources, for specific tracking projects, the Board has a very significant role to play in championing the overall aims of the proposed programme and facilitating collaboration and coordination. Provision of seed-corn funding as with the SALSEA Programme might be invaluable in raising the substantial funds needed to implement the proposed programme.

Further development of the proposal will require the engagement of the specific salmon research teams that will undertake the research so that they can plan and cost the detailed requirements for tagging and tag detection systems. It is proposed that this should be initiated through a Workshop which might initially be led by co-convenors appointed by the IASRB. This group will also need to engage with research groups working on other species as well as other research and industrial partners.

A preliminary Ocean Tracking Workshop of this nature, organised by IBIS and AST, was held in Newry, Northern Ireland in the fall of 2013. Details of the presentations and the recommendations arising from this workshop are available on: http://ibis-eu-know.weebly.com/sep-2013---ocean-tracking--newry.html. The co-conveners of the IASRB Workshop should reference this previous effort when developing the workshop agenda.

Summary of Next Steps for the International Acoustic Tracking Programme.

Date	Who	Action
June 2014	Sub-Group on Telemetry	• Seek SAG/IASRB support in principal for the research programme.
June 2014	SAG/IASRB	• Decide whether to support the proposed programme and the nature of that support. If there is support: • Develop a resolution from IASRB outlining the need for a large scale tracking effort • Appoint co-convenors to establish one or more Workshops, partially funded by IASRB, to discuss the further development of the programme. • Agree clear Terms of Reference for the Workshop(s) • Provide funds to facilitate the involvement in the Workshop(s) of the leaders of key research groups that would participate in a collaborative international programme. (It may be appropriate to

		have separate Workshops for NEAC and NAC programmes or for post-smolt and adult tagging programmes). IASRB has already agreed to support the workshop (£6,000) but additional funds may be needed • NB: the Workshop need to involve the groups who will potentially undertake the research and so the convenors, with advice from the SAG, should approach the most likely key players and invite them to participate.
Autumn 2014	Workshop	Meet to: • Develop an inventory of ongoing and planned marine telemetry studies on Atlantic salmon; • Develop an inventory of ongoing and planned telemetry studies on other species in the areas of the North Atlantic frequented by salmon; • Develop an inventory of the current (temporary and permanent) and planned location of acoustic receiver deployments in the areas of the North Atlantic frequented by salmon; • Recommend areas where collaborative programmes are most likely to provide the best partitioned estimates of mortality of emigrating post-smolts from multiple rivers with an outline of the scale and cost of such studies; • Identify strategic partners that may assist with implementation of proposed new activities • Advise on appropriate linkages with existing or planned ocean tracking programmes, both on the high seas and near shore / in estuaries. • Explore options for tagging adult salmon in the sea and recommend areas where programmes are most likely to provide estimates of mortality; • Establish one or more Steering Committees to develop more detailed plans for co-ordinated telemetry studies in selected areas and to seek funding.
Ongoing	Steering Committees	• Develop detailed research plans for specific areas of the telemetry programme, including tagging sites, location of receivers and receiver arrays. • Estimate costs and timescales for proposed activities • Identify potential research funding sources and seek opportunities for support funding, particularly from Ocean Foundations, industry and other marine conservation bodies. • Formalise links with key industrial (e.g. manufacturers) and strategic (e.g. OTN) partners • Formalise links with strategic partners working with other species that may benefit from collaboration • Outline of tasks to be completed to implement the plan

Annual Meetings	IASRB/SAG	• Review Steering Committee plans and advise on ways to improve coordination between studies • Receive proposals from Steering Committees for potential provision of support as appropriate. • Review progress with the overall programme and determine how to facilitate future activities. • Ensure continued co-ordination of the overall programme.

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Annex 1: Index rivers that might be used to provide smolts for tracking studies

NEAC Area (from ICES 2013):

France	River Nivelle Scorfe Oire and Bresle
UK(England & Wales)	Rivers Dee Tamar Frome
UK(Northern Ireland)	River Bush
UK(Scotland)	North Esk Girnock Burn
Ireland	Rivers Burrishoole Corrib Shannon Erne Screebe Delphi Lee
Norway	Rivers Halselva Imsa Drammen
Sweden	River Lagan
Russian Federation	River Kola Tuloma

NAC Area:

US	Penobscot River East Machias River Kennebec River Narraguagus River Sheepscot River Kennebec River
Canada	Nashwaak River, Big Salmon River LaHave River Middle River Miramichi River Restigouche River Saint-Jean River Ste. Marguerite River de la Trinité River Conne River Rocky River Northeast Trepassey River Campbellton River Western Arm Brook Sandhill River Saint John River (hatchery stock)