ICR(15)3

Report of NASCO's International Atlantic Salmon Research Board's Telemetry Workshop

NEAFC Headquarters, 22 Berner's Street, London, W1T 3DY
1 – 3 December 2014

1. Opening of the meeting

1.1 The Co-Conveners, Mr Ted Potter (EU) and Mr Tim Sheehan (USA), opened the meeting and welcomed participants to London. The Secretary of NASCO and the International Atlantic Salmon Research Board (IASRB), Dr Peter Hutchinson, added his welcome and thanked participants for agreeing to contribute to the future work of the Board in developing an international telemetry programme. He thanked NEAFC for allowing the Workshop to be held at its Headquarters and the Co-Conveners for their preparations for the meeting.

1.2 Mr Potter provided the background to the reasons for the IASRB hosting the Workshop. He indicated that the IASRB had been established in 2001 to promote collaboration and cooperation on research into the causes of the increase in marine mortality of Atlantic salmon and the opportunities to counteract it. In 2005, the IASRB had adopted an international cooperative research programme, the SALSEA Programme, which outlined a wide range of research on factors that may affect marine survival. The IASRB agreed that its specific focus should be on the research areas requiring substantial international coordination, namely migration and distribution of salmon at sea. Under this programme there had been marine surveys in both the North-East (SALSEA-Merge) and Northwest (SALSEA North America) Atlantic, enhanced sampling of the fishery at West Greenland (SALSEA West Greenland) and other smaller-scale projects.

1.3 Following completion of these projects, in 2013 the IASRB had reviewed its research priorities and had agreed that a particular focus for future work should be studies to partition mortality of salmon among the phases of the marine migration. It had, therefore, established a Telemetry Sub-Group that had reported in 2014. The continuing need to identify the presence, timing and location of survival bottlenecks for salmon at sea was recognised by the IASRB, and it had charged the Telemetry Sub-Group with developing a 'roadmap' outlining an international collaborative telemetry project to monitor the progress of salmon along their migration routes, to and from the marine feeding areas, and to estimate stage/area-specific mortality rates. He indicated that, in order to facilitate this process, the Board had decided to host a Telemetry Workshop to serve as a catalyst by bringing together and encouraging appropriate scientists to pursue large-scale international collaborative telemetry studies. He thanked all participants for contributing to the

Workshop and for providing information for inclusion in the inventories of ongoing and planned telemetry studies. The Ocean Tracking Network (OTN) had provided a considerable amount of information for the inventories and he thanked Dr Whoriskey for this valuable contribution.

1.4 A list of participants is contained in Annex 1.

2. Nomination of a Rapporteur

2.1 The Secretary was appointed as Rapporteur for the meeting.

3. Adoption of the Agenda

3.1 The Workshop adopted its Agenda, SRBTW(14)2 (Annex 2).

4. Consideration of the Terms of Reference

4.1 In light of the recommendations from the Board's Telemetry Sub-Group (see SAG(14)4), the IASRB had resolved to support and facilitate the development of an international telemetry programme with the objectives of monitoring progress of salmon along their migration routes to and from the marine feeding areas and estimating stage- and area-specific mortality rates of these salmon during the marine phase of their lifecycle, including the transition from the freshwater to the marine environment. In order to proceed with the development of this programme, the IASRB had decided to convene a Workshop with the following Terms of Reference:

- 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, including equipment manufacturers, 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 coordinated telemetry studies in selected areas and to seek funding.

4.2 The Workshop discussed whether the IASRB's intention was to establish a long-term monitoring network of acoustic arrays or to undertake specific shorter-term projects aimed at better understanding factors affecting marine mortality in particular areas and at specific times. It was noted that acoustic tracking projects in the Gulf of Maine and Gulf

of St Lawrence had 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 and importantly its variability among years. The acoustic tracking studies in North America had been initiated with short-term funding with renewals allowing long-term data sets to develop over time. The ability to build or maintain long-term data series in these circumstances can be problematic. Nevertheless, it was suggested that a similar approach might be used in other parts of the North Atlantic, noting that some funders, including the European Commission, would only support projects that would deliver results in three to five years. It is anticipated that the proposed programme would seek to build on the success of the North American studies to extend the areas and times for which information on marine mortality is available around the North Atlantic and that there would be a role for coordination of these through the IASRB.

4.3 It was noted that the priority is to estimate mortality rates in the first year at sea and that improved knowledge of distribution and migration would assist in identifying the factors responsible (e.g. aquaculture, renewable energy installations, climate change). However, studies on adult salmon could also provide valuable information that could inform ICES assessment models. Data logging 'pop-off' satellite transmitters applied to salmon caught at West Greenland and kelts returning to sea after spawning have demonstrated the potential to increase understanding of the migration routes and behaviour of salmon at later life stages and the factors affecting them. It is hoped that these programmes can also be developed and expanded. It was noted that the causes of marine mortality may be natural or anthropogenic and knowledge of the cause of mortality is required before remedial action can be considered.

4.4 Clarification was sought as to NASCO's research priorities. The Workshop was informed that the IASRB, which reports to the Council of NASCO and comprises representatives of each NASCO Party and NASCO's accredited NGOs, had agreed that, building on the success of the SALSEA Programme, it wished to encourage studies to partition marine mortality of migrating Atlantic salmon. At its 2014 meeting, the IASRB had unanimously adopted a Resolution on Research on Salmon at Sea, ICR(14)10, encouraging NASCO Parties to continue the development of local collaborative telemetry projects, encouraging the development of large international collaborative telemetry projects that together build upon and expand local efforts, and requesting that NASCO Parties make efforts to identify funding sources to support telemetry projects. Copies of the Resolution were made available to the Workshop participants. The Workshop agreed that the output from its meeting would be a report which would outline possible telemetry studies to address the IASRB's research priority of partitioning marine mortality of Atlantic salmon with a focus on mortality in the first year at sea. The report would also make recommendations for the establishment of Steering Committee(s) to refine the studies, identify strategic partners, possible funding options, and timelines and advise on the future role of the IASRB.

5. Development of inventories of ongoing and planned marine telemetry studies

5.1 Mr Sheehan reported on progress in establishing inventories of ongoing and planned marine telemetry studies. Prior to the Workshop, participants had been requested to provide summary information on ongoing and planned tracking programmes including details of the tagging agency, the country, the location/river where acoustic receivers had been or are planned to be deployed (i.e. in-river, estuary or coastal/oceanic), the general area or latitude and longitude of the receivers in the marine environment, the species being studied and contact details. In addition, considerable information had been provided by

the OTN, with regard to the location of individual receivers in their database, and obtained from miscellaneous reports. While the data were not complete a substantial overview of North Atlantic telemetry assets had been prepared and was presented to the Workshop.

NASCO Commission area	Number of active receiver assets
NEAC	84
NAC	709
WGC	0

Table 1: *Inventory of individual receiver assets included within the OTN database by NASCO Commission area*

	Freshwater		**Estuarine**		**Coastal/oceanic**	
	Current	Planned	Current	Planned	Current	Planned
North-East Atlantic Commission (NEAC)						
Belgium	1	-	1	-	1	-
Denmark	-	-	-	-	2	-
Ireland	6	-	6	3	4	-
Norway	1	1	4	3	4	3
UK (England and Wales)	4	2	3	3	3	2
UK (Northern Ireland)	2	1	2	-	1	-
UK (Scotland)	-	-	-	2	-	2
Total	**14**	**4**	**16**	**11**	**15**	**7**
North American Commission (NAC)						
USA	1	-	1	-	1	1
Total	**1**	**-**	**1**	**-**	**1**	**1**
West Greenland Commission (WGC)						
USA	-	-	-	-	-	1
Total	**-**	**-**	**-**	**-**	**-**	**1**
Grand Total	**15**	**4**	**17**	**11**	**16**	**9**

Table 2: *Summary of current and planned telemetry monitoring projects of which the Workshop participants were aware in freshwater, estuarine and/or coastal/oceanic environments by NASCO Commission area and jurisdiction not accounted for in the OTN database. Project entries could represent single receiver or multiple receiver deployments.*

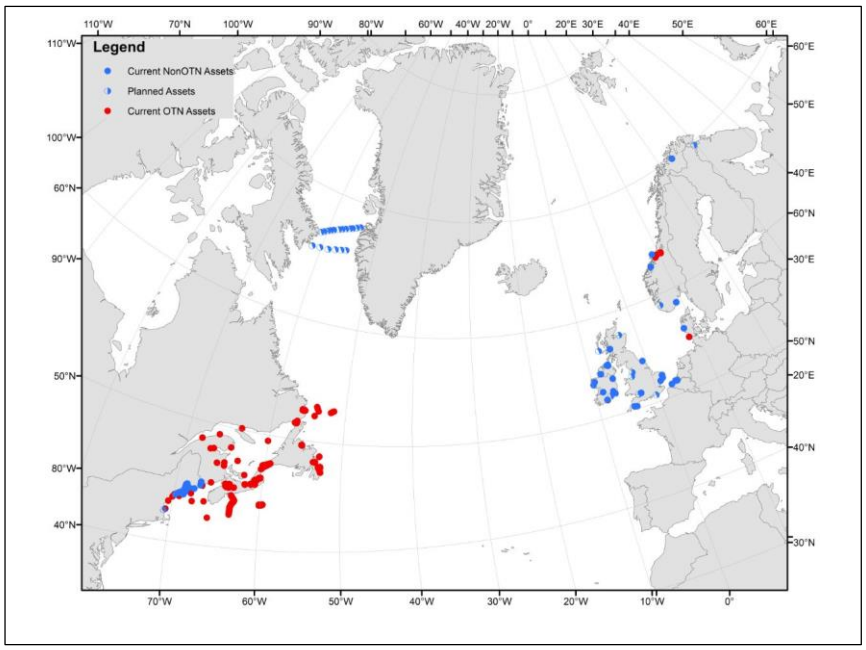

Figure 1: *Current and planned telemetry assets in the North Atlantic. Current assets represent individual receiver locations and were provided by OTN. Details of non-OTN assets were provided by the Workshop participants or obtained from miscellaneous reports and may represent single or multiple assets.*

5.2 There were marked differences in the resolution of the data, with detailed information provided by OTN but more general information provided by the Workshop participants. It was noted that there was limited current deployment of OTN receivers in Europe although several projects of potential use for salmon tracking are under negotiation. The Workshop also noted that a major project proposal, Coast Track, had narrowly failed to obtain funding from the EU under the Seventh Framework Programme, but the reasons for its lack of success were not known. Reference was made to a proposed oceanographic monitoring programme at West Greenland that if successful would result in two lines of buoys from Baffin Island across to West Greenland (~300km) to which receivers could be added. A summary of the collated information is presented in Tables 1 and 2 and displayed in Figure 1.

5.3 Other potential assets include miscellaneous bioprobes, drifters, autonomous underwater vehicles (AUVs also known as gliders), oceanographic buoys, ocean monitoring stations and buoys attached to fixed fishing gear. Information was presented indicating that the OTN had recently successfully deployed AUVs (Wave Gliders®) along the Halifax acoustic receiver line, which runs from the shore to approximately 250km offshore, upload data from bottom-mounted acoustic receiver models equipped with acoustic modems and then transmit that data back to shore via satellite. Using AUVs to download receiver data would result in significant cost savings for managing these types of programmes as expensive ship time is no longer required to download data. AUVs can also serve as mobile receivers listening for tagged animals.

5.4 OTN has tagged and released grey seal 'bioprobes' on Sable Island, Nova Scotia, Canada. These seals each carry a satellite tag to record location and oceanographic conditions, as well as an acoustic transmitter/receiver. The receivers will detect and record the approach (within approximately 0.5km) of other tagged animals. Such bioprobes have been used in studies on seal-cod interactions since 2001 and they may also be useful in studies under sea ice.

5.5 NOAA Fisheries uses oceanographic buoys and other platforms of opportunity to detect acoustically tagged salmon in the Gulf of Maine. These platforms of opportunity have resulted in large numbers of detections of numerous different species tagged and released by a large number of different tagging groups in North America.

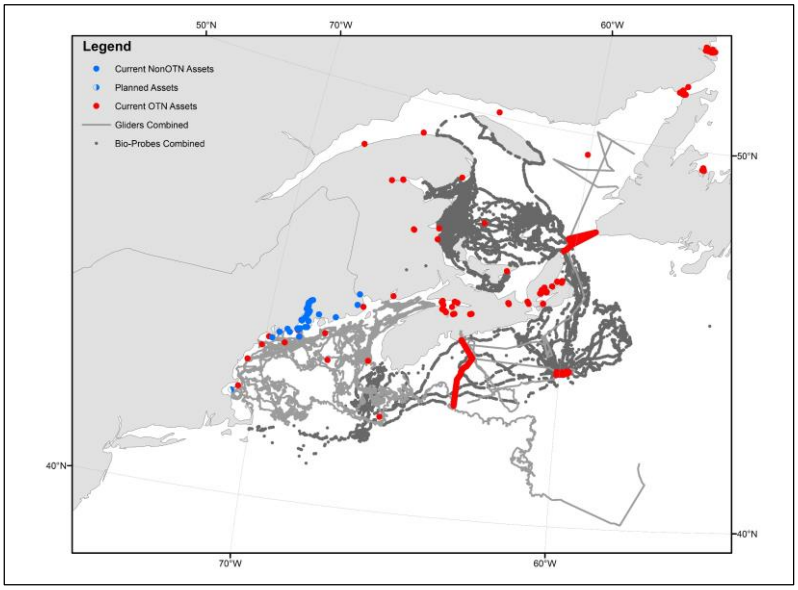

Figure 2: *Maps showing the spatial coverage of all assets types deployed or planned to be deployed (prior to the workshop) within the North American Commission. Assets included current and planned receiver locations overlaid with drifters, bioprobes and gliders tracks. The figure is designed to show the extent to which the area could be covered by telemetry monitoring assets if all deployment efforts were coordinated in time and space.*

5.6 It was noted that the majority of global telemetry equipment in the marine environment is manufactured by Vemco, but it was recognised that there could be local 'hotspots' of gear from other manufacturers such as Thelma Biotel, Lotek and Starr Oddi (see paragraph 7.2 below). At present, there are limited OTN assets in Europe, yet there is a large number of scientists using the technology for focussed individual studies in Europe. If these investigators could be brought together into a network, great potential exists to expand geographic coverage in the region through sharing of detections among researchers and to foster collaborative research. The AtlantOS Horizon 2020 programme (Blue Growth 8 call) has been invited to the grant phase, and includes a Work Package to begin to develop a European Aquatic Animal Telemtry Network. Funding for this work may begin to flow as early as April 2015. Tracking of salmon post-smolts in the NEAC area has predominantly been conducted within estuaries and fjords and it has not extended as far from the rivers as it has in the NAC area. A major telemetry-based research proposal, CoastTrack, had narrowly failed to secure EU funding under the Seventh Framework Research Programme (FP7) but a tracking programme on eels (EELIAD) had been successful. It was noted that links have been made in the Northwest Atlantic between researchers working on salmon and other species so that information on detections is exchanged but these links are less well developed in the North-East Atlantic.

5.7 The Workshop noted the findings from a recent study conducted at the University of St Andrews (www.abc.net.au/science/articles/2014/11/19/4131980.htm) that claimed that acoustic tags on fish may aid predators in detecting prey, potentially increasing predation of tagged animals and possibly skewing study findings – the so-called 'dinner bell effect'. The study had been conducted in laboratory conditions and not in the wild. It was noted that only a tiny fraction of wild smolts are being tagged and so the chance of seals learning

this behaviour in the open ocean was very small; in addition the predators of seals (e.g. large sharks) are also being tagged which could negatively condition seals to signals from acoustic tags. The Workshop noted that it would be valuable to undertake investigations into the effects of tagging on survival of salmon and this could be done by tagging groups of fish at different intervals before their release. Where PIT tags are already being applied to salmon, a proportion of the fish could also be tagged with 'dummy' acoustic tags to detect differences in survival between tagged and untagged fish. If both 'dummy' and real acoustic tags were used then the 'dinner bell effect' could be tested in the wild.

6. Identification of the most suitable areas for new collaborative telemetry studies (ToR 4 & 7)

6.1 As previously indicated, studies involving acoustic tracking of post-smolts have been ongoing in the North American Commission area for many years (including in the Gulf of Maine and Gulf of St Lawrence) and have successfully tracked fish from rivers draining into the Gulf of St Lawrence (through the Strait of Belle Isle and the Cabot Strait) and from rivers draining into the Gulf of Maine up past Halifax, Nova Scotia, Canada. In comparison, many studies in the North-East Atlantic (NEAC) area have been confined to estuary or fjord limits. The Workshop divided into three groups, on the basis of NASCO Commission areas, to consider ideas for new collaborative telemetry studies. It was noted that it would be important to develop links with groups working on acoustic telemetry with other species but the salmon projects should be steered by researchers working on salmon.

(a) North American Commission (NAC) area

6.2 The Workshop noted that the objective of the IASRB is to obtain information on mortality of salmon at sea and that there have been ongoing acoustic tracking programmes, and considerable assets deployed, in the Gulf of Maine, Gulf of St Lawrence and off the coast of Halifax which have confirmed the potential of acoustic tagging to address the IASRB's objectives. Discussions were held on what further research might be needed in the North American Commission area.

6.3 Dr John Kocik (NOAA) indicated that studies on the Penobscot and Narraguagus rivers had indicated that, for the first partition, approximately 50% of tagged smolts were lost in the estuary and it would now be valuable to determine the factor or factors responsible for inter-annual variability in this mortality. The next partition indicates that of the smolts entering the Gulf of Maine approximately 25 - 30% reach the Halifax acoustic receiver line 21 – 24 days later. He indicated that the receivers in the nearshore Gulf of Maine had a spacing of ~400m resulting in a detection efficiency of approximately 97%. It was noted that detections of post-smolts on the Halifax receiver line were concentrated in the area from 20 to 50 km offshore and so it was not felt that many fish went round the line. However, some individuals were detected along the entire length of the line which extends >100 nautical miles offshore, and the detection efficiency of the Halifax line (800m spacing) is thought to be between 50 - 100% depending on conditions. The Workshop discussed whether there would be merit in installing a second Halifax line or reducing the spacing of the receivers in the existing line. It was noted that the last array along the migration pathway is always the most problematic for statistically robust estimates of mortality rates. However, the terminal arrays could still provide minimum estimates of mortality to that point in the migration. While a second line would improve the detection efficiency and therefore provide more data on migration dynamics and more robust estimates of survival, because of its length it would be expensive (257 units would cost

approximately $1 million). An alternative might be to add extra receivers to the line at the points where most salmon detections are made. Interest was also expressed in a full-grid design array rather than a line allowing accurate positioning by triangulation. Since approximately 75% of the mortality appears to occur in the first few weeks at sea, it may not be cost effective to move further offshore to study the remaining 25% of mortality. However, a lower percentage of smolts leaving fjords in Norway die in the early marine phase so there may be merit in siting arrays further offshore in the NEAC area.

6.4 Mr Jon Carr (Atlantic Salmon Federation) reported on ongoing projects being conducted by the Atlantic Salmon Federation (in collaboration with the OTN, Miramichi Salmon Association, DFO and others) to assess estuarine and marine survival of tagged Atlantic salmon released in rivers of the Gulf of St Lawrence. Acoustic arrays have been installed across both the Strait of Belle Isle and, since 2012, across the Cabot Strait, effectively providing an acoustic 'gate' to count fish as they exit from the Gulf of St Lawrence. Few post-smolts appear to use the Cabot Strait as an exit from the Gulf of St. Lawrence although the array is deep and there are concerns about the detection efficiency of the currently deployed receivers. A total of 248 smolts (24 St Jean, 39 Cascapedia, 105 Miramichi, and 80 Restigouche) and 41 kelts (16 Miramichi and 25 Restigouche) were acoustically tagged in 2013. Of the 41 kelts, 11 from the Miramichi were also tagged with archival pop-up tags; these were set to release after four months and information was derived from seven of the tags that left the Miramichi River, two of which transmitted information from the northern Labrador Sea in early September.

6.5 Mr Carr indicated that the OTN Wave Glider® was used within the Gulf of St Lawrence to detect acoustically tagged salmon. The movements of the Wave Glider® were controlled to pass through areas expected to contain tagged post-smolts and kelts on their migration through the Strait of Belle Isle. Four salmon kelts were detected. He indicated that there is also interest in tagging salmon in the Inner Bay of Fundy with a view to identifying critical habitat and investigating aquaculture interactions and to seek cooperation from those involved in research on eels and striped bass. However, it was recognised by the Workshop that Inner Bay of Fundy stocks undertake limited marine migrations so the findings, although of interest to the management of these particular stocks, may be rather specific to that area.

6.6 Consideration has also been given to installing an acoustic array off Labrador (and to tagging smolts in the Goose River, Labrador) and to installing a second array in the Strait of Belle Isle to better assess salmon survival to this point in the migration. There was also a concern about whether tag battery life would be adequate to allow tracking of tagged smolts to an array off Labrador, although it was noted that V8 and V9 tags have a battery life of 6 months and could be applied to smolts >13 cm in length. Mr Carr noted that there is some uncertainty about where best to site new lines and consideration is being given to migration modelling to inform any such decisions. A second array would allow mark – recapture estimates to be made of mortality.

6.7 Mr Carr indicated that the ASF is also interested in acoustic tagging of salmon at West Greenland. If genetic samples of tagged fish were taken at the time of tagging, they may be assigned to their river/region of origin (e.g. originating from the Gulf of St Lawrence) and receivers could be deployed to detect their return. The view was expressed that satellite tagging might be more appropriate for salmon in their second summer at sea and that such tags are particularly suited to migration studies. It was noted, however, that large tags (e.g. Pop-off Satellite Archival Tags or PSATs) can affect subsequent survival of tagged fish depending on capture method, handling of the fish and tag application.

6.8 The Workshop discussed whether or not tagging of kelts (using larger, longer life acoustic tags) could be used as a surrogate for smolt tagging. It appears that for some stocks in the NEAC area there is similarity in the migration routes of smolts and kelts. Studies in the Gulf of St Lawrence indicate that kelts that spawn in alternate years do follow similar migration routes to post-smolts, as they both exit the Gulf of St Lawrence though the Strait of Belle Isle, but those spawning in consecutive years probably remain inside the Gulf of St Lawrence. It was also noted that while post-smolt survival is declining, kelt survival in some circumstances is increasing. However, valuable information might still be obtained by tagging kelts particularly with regard to migration and distribution and mortality vectors.

6.9 With regard to new studies in the NAC area, the Workshop discussed approaches to improving detection efficiency of existing deployments (including installing new receiver lines/grids in the Strait of Belle Isle, off Labrador and off south-east Newfoundland, and use of platforms of opportunity, drifters and AUVs), additional releases of tagged fish and collaboration with researchers working on species other than salmon. The Workshop developed, in outline, a number of new telemetry projects for the NAC area and these are described in section 7 below.

6.10 It was noted that it would be valuable to develop a North Atlantic-wide inventory of platforms of opportunity (e.g. oceanographic buoys, oil rigs etc.). The workshop participants were informed that funding for this effort has already been secured and that the work will commence by OTN in the near-term. Since these assets (arrays, buoys, oil rigs, ocean monitoring stations, AUVs etc.) are widely dispersed there would need to be careful consideration given to how downloading of data could be managed.

(b) North-East Atlantic Commission area

6.11 The Workshop recognised that compared to the NAC area there were fewer opportunities in the NEAC area to site acoustic arrays that could close off areas of the marine environment into which multiple rivers flow as is the case for the Gulf of St Lawrence. Nonetheless, there had been several salmon smolt tracking studies in estuaries and for a limited distance offshore in several countries, including through fjords in Norway (up to 170km from river mouths to full sea water) and in Lough Foyle on the border between Ireland and the UK (Northern Ireland). Such studies may ideally be conducted on salmon index rivers where smolt trapping facilities already exist, but it was noted that there was a need for additional index river studies since there are large areas around the North-East Atlantic with no such sites. Reference was made to a feasibility study for deploying a line of receivers from Malin Head in Northern Ireland to the Scottish coast and the convenient location of index rivers in Northern Ireland (River Bush) and Wales (River Dee). There were considerable discussions about approaches to extending the detection further offshore, beyond estuaries and fjords, and some areas were identified where full arrays might be installed. The Workshop agreed that it would be important to establish a number of NEAC tracking studies before investing large sums in offshore work and that the feasibility of deploying arrays in the Norwegian Sea would need careful consideration given their potential length and the depth of the water.

6.12 The Workshop also discussed the role of migration models as a tool to assist in siting acoustic arrays. Reference was made to a particle drift model developed as an output from the SALSEA Merge project. It was noted that while migration models can be informative they depend on adequate input data to test migration paths and the particle (fish) behaviour. The SALSEA-Merge model was believed to assume that much of the

movement of post-smolts was a result of passive tidal transport. Such a model may not accurately portray smolt migration in areas where smolts leaving freshwater have to migrate significant distances against the residual coastal and oceanic currents. Nevertheless, it was also suggested that variation in wind driven currents could have marked effects on migration routes and that modelling might assist in this regard. The utility of using smolt migration models for designing large scale telemetry monitoring projects should be considered further.

6.13 Another approach to planning receiver deployments may be to initially establish 'porous' arrays, with widely spaced receivers, or receivers on buoys in a number of locations in association with tagging in several rivers in a region. It was noted that initial trials with such arrays and offshore gliders in the NAC area might inform studies in the NEAC area. Additional receivers might then be deployed as information was gathered of the detection 'hot spots' i.e. a progressive approach. The question arose as to how funders would perceive such a progressive, stepwise approach compared to a large initiative and it was suggested that funding from the EU would probably require results in a three to five year period. It was noted that the systems deployed in the Gulf of St Lawrence have developed over a period of years and that alternative funding mechanisms would need to be identified that permitted the staged development of a network of individual receivers and arrays.

6.14 There were discussions about an appropriate approach to tagging adult salmon and whether this should involve applying PSATs to fish caught, for example at Faroes or Spitzbergen, or to kelts in rivers. It was recognised that salmon from many river stocks occurred in the waters around the Faroes and that there had been no fishery there for many years. However, if there was interest in conducting a limited research or experimental fishery in the future PSATs might be applied at reasonable cost, although the tags themselves are expensive (~$4,000 each) and there were challenges in using fish caught by long-lines. In these circumstances, consideration might be given to further kelt tagging as a method of obtaining information on marine mortality of salmon after their first summer at sea. Issues concerning whether kelts can be a surrogate for either post-smolt or maiden adult fish are discussed in 6.8 above and 6.18 below.

6.15 On the basis of the discussions outlined above, the Workshop considered a number of approaches to partitioning marine mortality of salmon in the North-East Atlantic including:

- better coverage of basic index river studies using a range of methods (CWTs and PIT tags) in order to provide estimates of return rate (not natural mortality) for the marine phase;
- integrated acoustic tagging as part of index river studies to provide estimates of natural mortality to headland limits (estuaries, fjords and including the freshwater/saltwater transition);
- adoption of various approaches to partition mortality in the next marine phase for different index river stocks, recognising that there is limited data on migration routes (see map below of possible approximate sitings of arrays which would all be final arrays so potentially poor estimation of mortality):
    - West coast Scottish arrays (full arrays with high detection efficiency);
    - Malin Head, Northern Ireland (full array with high detection efficiency);
    - North Sea (loose array based on existing platforms of opportunity using information from OTN);

- Norwegian coast, north and south gateways.

- consideration studies out into the Norwegian Sea and using drifters/AUVs etc. if this approach proves to be valuable in the North American commission area;
- development of a single integrated EU funded programme.

(c) West Greenland Commission area

6.16 Mr Sheehan indicated that PSAT technology is generally suitable for work with Atlantic salmon of the size range at West Greenland although there is a need to refine the catch methods (gill nets) and tagging techniques. Detailed information on migration routes, migration rates and environmental conditions experienced can be derived from the data obtained. He reported on investigations into the migration over the autumn and winter of salmon tagged at West Greenland in September 2010, 2011 and 2012. PSATs were attached to 25 Atlantic salmon and preliminary results suggest that two tags remained on the fish until the programmed pop-off date (April 1), three fish were predated, eight popped off for unknown reasons, and twelve did not transmit any data for reasons that are unknown but need to be determined. The existing data are currently undergoing full analysis but there is interest in planning for extending the preliminary studies and possibly in including acoustic tags.

6.17 These studies can provide valuable information on mortality of adult salmon to inform ICES assessment models (e.g.in order to improve confidence in the natural mortality values (M) for adult salmon in the sea) and on migration dynamics which can be informative of larger ecological based questions and investigations. These are currently based on the mortality schedule model. It was noted that PSATs cost around $4,000 each and that they provide information only about the individuals tagged whereas acoustic systems are more ecosystem oriented allowing for collaboration with those working on other species. There is some uncertainty about the continuation of support for the operation of the Argos satellite network and any future PSAT tagging programme would be dependent on the availability of this or an alternative monitoring platform.

6.18 The Workshop discussed the relative merit of tagging non-maturing 1SW salmon at West Greenland or kelts in homewaters. It was noted that tagging kelts could provide 6 - 12 months of data but that there was interest in determining survival from the feeding grounds back to homewaters for use in the ICES assessment models but it was unclear if tagging kelts could provide this information. It was also noted that the proportion of Southern European salmon at West Greenland has declined in recent years and is currently around 20%. As a result few tagged salmon at Greenland would be expected to return to European rivers.

7. Recommendations for the development of detailed plans for projects in selected areas and approaches to fund-raising (ToR 8), identification of strategic partners and appropriate linkages to existing and planned tracking programmes, etc. (ToR 5 & 6)

7.1 Before considering approaches to developing detailed plans for projects in selected areas and approaches to fund-raising, the Workshop considered developments concerning tag technology and discussed compatibility issues. The Workshop noted that for satellite tags there should be no issue of compatibility provided that the tags can upload their data to the ARGOS satellite or its successor. However, it was recognised that there are several manufacturers of acoustic tags and receivers although the majority of the equipment deployed in marine environments worldwide is manufactured by Vemco with currently

approximately 25,000 receivers deployed. It was noted that some funding agencies have strict rules concerning competitive tendering for equipment, including the EU.

7.2 Mr Mark Jollymore, President and CEO of Vemco, provided an update on developments in tag technology and Vemco's position on compatibility. He indicated that, at the request of its customers, Vemco had primarily focused on smaller transmitter technology, aimed at salmon smolt research but also for use on many other species. With the introduction of the V4 transmitter weighing only 0.4g, it seems likely that transmitters are now small enough for most applications, but the development of smaller transmitters may be possible if there is a demand. He indicated that Vemco is presently focusing on various forms of sensors for its products and is in the early phases of testing a predation transmitter and dissolved oxygen sensor with a view to having these commercially available in the next two years. In addition, Vemco is ready to release integrated acoustic release and transponding receivers to the market and currently has a high-residency receiver in beta test. These new transmitters and receivers are part of a very high level of investment in recent years to bring new tools and technology to the research community. He noted that considerable competition exists within the fish research community between technologies and tools (e.g. satellite tracking, archival tagging, acoustic telemetry) and also specifically within acoustic telemetry (e.g. Vemco, Thelma Biotel, HTI, ATS, Lotek). In several cases of this competition, the technologies co-exist without interfering or compromising the data integrity being obtained. This encourages investment in new technologies and products for the community. He stated that in cases where claims are made that the products are compatible with the Vemco system these claims are false; those products claiming compatibility are the result of deliberate efforts to reverse engineer the Vemco developed and proprietary system and thereby compromise the integrity of the global coding system by duplicating codes. Furthermore, Vemco will be evolving its worldwide coding systems as it brings new technologies and tools to the research community without regard for these cloned tags and receivers and will thus render the clones incompatible in part or in whole.

7.3 The Workshop was advised that OTN intends to develop an inventory of platforms around the North Atlantic and Dr Whoriskey agreed to keep the IASRB informed of developments in this regard via the NASCO Secretariat.

7.4 The Workshop developed outline project plans for future telemetry-based studies to address the approaches discussed above (section 6) to estimate and partition marine mortality of salmon and improve understanding of migration and distribution patterns. Each of the proposed plans, provides the following information:

- Testable hypotheses;
- Potential project leaders;
- Equipment and support needs;
- Equipment manufacturers;
- Potential timelines for field work and duration;
- Potential linkages and partners;
- Funding options;
- Ball park budget costs.

7.5 The following outline project plans are initial working documents developed in the limited time available at the Workshop; they will need further development over time and their implementation will be dependent on funding being available:

North American Commission (NAC)

- Drifters and Bioprobes: Options for detecting acoustically tagged fish in large geographic areas (North American and/or North-East Atlantic Commissions), SRBTW(14)3 (Annex 3)

  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 drifters arrays may be informative in these areas. The Workshop was advised that there are new platforms being deployed (e.g. in the Labrador Sea by Laval University) but this project is a novel idea and would require funding. The IASRB might be able to assist with fund raising initiatives.

- New Receiver Lines/Arrays/Grids (North American Commission area), SRBTW(14)4 (Annex 4)

  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. The Workshop was advised that it is likely that the installation of at least one new array would proceed but priorities need to be resolved and funding secured.

- Platforms of Opportunity in the North American Commission area: Stationary Platforms of Opportunity Receiver Exchange (SPORE), SRBTW(14)5 (Annex 5)

  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. The Workshop was advised that such an approach will proceed in 2015 in the Gulf of Maine with a second phase being considered for 2016 – 2019. It is not clear if the approach will be implemented elsewhere.

- North American Commission kelt satellite tagging, SRBTW(14)6 (Annex 6)

  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. The Workshop was advised that ASF has been releasing a limited number of PSAT tags

on kelts from the Miramichi River over the past few years. There have been some preliminary discussions of expanding this effort to other river systems, both in USA and Canada, and effort towards this will likely proceed.

North-East Atlantic Commission (NEAC)

- Generic Index River Sites in the North-East Atlantic Commission area, SRBTW(14)7 (Annex 7)

  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 analyzing critical periods for mortality and possible causes of mortality.

- Malin Head to Islay Receiver Array (North-East Atlantic Commission area), SRBTW(14)8 (Annex 8)

  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? The Workshop was advised that if funding was secured, the aim would be to further investigate the early marine migration phase in the tidal river and L Foyle in 2016 and initiate a feasibility study on the Malin Head to Islay array. Progress would be dependent on its outcome.

- North Sea Loose Array (North-East Atlantic Commission area), SRBTW(14)9 (Annex 9)

  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. The aim would be to conduct the project during 2016 - 2019 if funding can be secured.

- West-coast Scottish arrays

  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 of development of investigations into possible interactions between aquaculture and wild salmon has been 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.

- Studies of migration along the European shelf edge and into the Norwegian Sea using drifters/AUVs etc., SRBTW(14)10 (Annex 10)

  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.

- North-East Atlantic Commission kelt satellite tagging, SRBTW(14)11 (Annex 11)

  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. The Workshop was advised that some work is already ongoing but other sources of funding would be needed to expand the research to other areas and in scale.

- Sub-adult satellite tagging at Faroes, SRBTW(14)12 (Annex 12)

  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.

West Greenland Commission (WGC)

- Adult satellite/acoustic tagging at Greenland, SRBTW(14)13 (Annex 13)

  This technology, in combination with genetic assignment methods, offers the ability to provide information on stock-specific migration routes, behavior and mortality during the second year at sea. The Workshop was advised that it is anticipated that there is a high probability that this work will be pursued but it will probably be dependent on additional funding being made available.

7.6 The Telemetry Sub-Group (see SAG(14)4) had suggested that the proposed telemetry programme should make best use of the fish capture facilitates on existing index rivers in the NAC and NEAC areas. Figures 4 and 5 below show the locations of current and historic smolt monitoring sites and potential smolt monitoring sites.

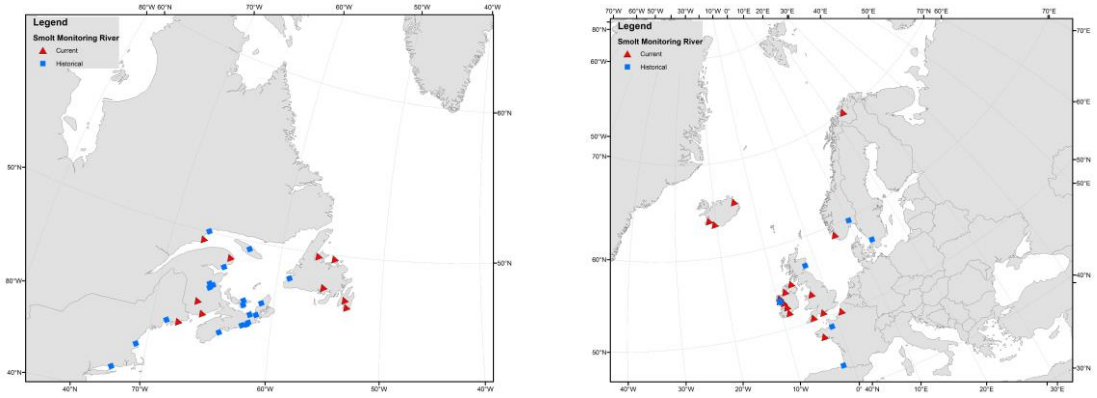

Figure 3: *Location of current and historic smolt monitoring sites in the NAC (left) and NEAC (right) areas. (Source: Report of the ICES Working Group on North Atlantic Salmon. Tables 3.3.6.1, 3.3.6.2, 4.3.5.1, 4.3.5.2, 4.3.5.3 and 4.3.5.4 ICES CM 2014/ACOM:09).*

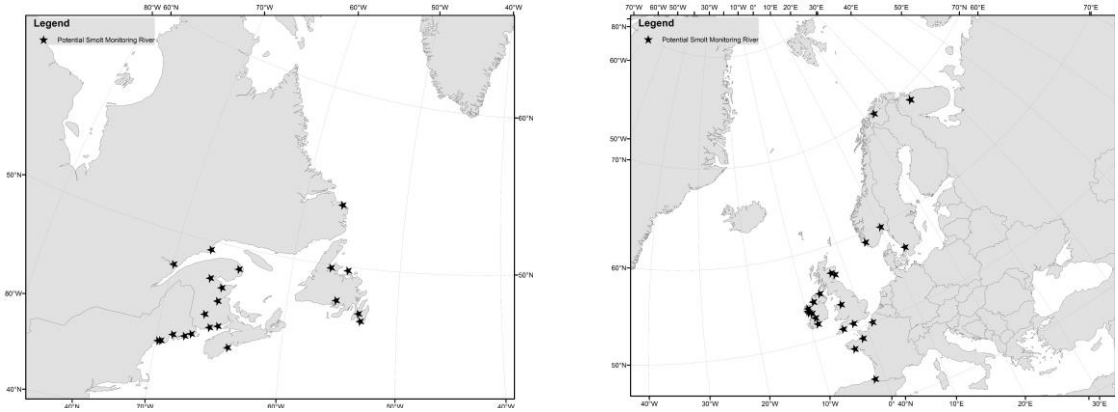

Figure 4: *Location of potential smolt monitoring rivers in the NAC (left) and NEAC (right) areas. (Source: Report of the SAG Sub-Group on Telemetry. (2014). Annex 1 of NASCO document SAG(14)4).*

8. Future role of the IASRB

8.1 The Secretary reported on the role that the IASRB had played in relation to developing, promoting, implementing and publicising the SALSEA Programme. He indicated that the Board had first developed an inventory of research to demonstrate the extent of research on salmon at sea being undertaken by NASCO Parties/jurisdictions their partners. This inventory was used to identify research gaps and priorities to inform development and implementation of the SALSEA Programme through a public/private partnership. The Board had been able to support implementation of the SALSEA Programme in a number of ways:

- NASCO had provided 'seed-corn' funding (£30,000) to support fund-raising initiatives and professional advisors had been engaged to develop an approach to fund-raising and identify potential funding sources. As a result of these initiatives substantial funding had been secured;
- Individual NASCO Parties/jurisdictions had contributed funds either to support the general work of the Board or to fund specific projects under the SALSEA programme. For example, the United States had provided funds to facilitate enhanced sampling under the SALSEA West Greenland project. Endorsement by the IASRB, and in some cases partial financial support, had enabled a number of projects to be undertaken including genetic stock assignment of historical samples from the West Greenland and Faroes salmon fisheries and most recently to a project that will enhance the North American genetic baseline and facilitate finer-scale assignment of samples from West Greenland;
- NASCO Parties/jurisdictions had supported research domestically as contributions to the SALSEA Programme e.g. vessel time was contributed by Canada and additional resources contributed by Canada and the United States to support SALSEA North America;
- The NASCO Secretariat and the Chairman of the IASRB had made representations to DG Research and DG Environment in support of the SALSEA Programme and this had led to substantial funds (£3.5 million) being awarded to the SALSEA-Merge project under the EU Seventh Framework Research Programme;
- The Secretariat and Chairman of the IASRB had sought funding from private sources and substantial funds had generously been donated to the SALSEA Merge project by the TOTAL Foundation (£200,000) and the Atlantic Salmon Trust. The Ocean Foundation had also expressed an interest in the SALSEA Programme but had not been able to contribute funds at that time.

8.3 The Workshop noted that at its last meeting, the IASRB had recognised that the SALSEA Programme had been well publicised and there was awareness of it among potential funders and that this could be built on with regard to future telemetry studies.

8.4 Professor Ken Whelan outlined a number of potential funding sources including the EU Horizon 2020 Programme. This Programme is the biggest EU Research and Innovation Programme with nearly €80 billion of funding available over 7 years (2014 to 2020). Funding opportunities under Horizon 2020 are set out in multiannual work programmes, which cover the large majority of support available, and they include a section on Climate Action, Environment, Resource Efficiency and Raw Materials the objectives of which include the protection and sustainable management of natural resources and ecosystems. Of the total funds available under Horizon 2020, €200 million was earmarked for marine

research and innovation over the first two years of the Programme (2014/15) although this initial allocation will already have been committed to projects. He noted that there is considerable interest in the Commission in better understanding impacts of aquaculture escapees and appropriate management measures to minimise them. He also referred to the recently signed Galway Agreement on Atlantic Ocean Cooperation which is a commitment to connect the ocean science capacity of EU, Canada and the United States with a joint focus on the North Atlantic Ocean, including its connections to the Arctic Ocean and the Mediterranean Sea. The goal is to better understand the Atlantic Ocean and promote the sustainable management of its resources. He suggested that it would be important to influence national representatives with regard to the next framework programme in 2018 and that there may be funding opportunities under other EU initiatives such as COST actions and the LIFE Programme. In this regard he suggested that it would be helpful for the Secretary to update key contacts in DG Environment and DG Research on developments since the completion of the SALSEA-Merge project, and to offer that the Secretary and IASRB Chairman or one of the Workshop Co-Conveners meet with them. Professor Whelan agreed to provide the contacts details to the Secretary.

8.5 As noted by the IASRB's Telemetry Sub-Group, the proposed international telemetry programme is an exciting 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 organisations focused on a variety of other marine species that utilise the North Atlantic and Arctic Oceans. It will, therefore, further raise the profile of NASCO as a leader in marine resource management. The Workshop recognised that the IASRB could play an important role by serving as a forum for information exchange and collaboration among research groups, by facilitating coordination (e.g. on the use of equipment, the tagging activities and the operation of detector arrays over large geographic areas), by supporting fund-raising initiatives and by providing funds as resources permit. While Steering Committees were not established for each project during the Workshop, potential project leaders were identified in the project plans and it is hoped that they will liaise with the IASRB through the NASCO Secretariat to provide updates on progress and in the event that they feel the Board can assist in taking the projects forward. In this regard, it was noted that the IASRB Sub-Group on the Future Direction of Research on Marine Survival of Salmon, SAG(13)2, had indicated that the Board has very limited resources and had recognised that if it is to continue to play a role in supporting research on salmon at sea it should consider how it can address that situation. The Workshop recommended that the Secretary should write to DG Research and DG Environment to update key contacts on the work of the Board since the completion of the SALSEA-Merge project and in particular its interest in acoustic telemetry studies to partition marine mortality.

9. Any other business

9.1 The Workshop was advised of a further telemetry Workshop that is being held in late January by the Norwegian Institute for Nature Research (NINA) and Inland Fisheries Ireland (IFI) in order to share and improve skill sets and knowledge in aspects of telemetry, and to support development of an expert network, with a view to future project collaboration.

10. Report of the Meeting

10.1 The report of the Workshop was agreed by correspondence after the meeting.

11. Close of the Meeting

11.1 The Co-Conveners thanked participants for their contributions and closed the meeting.

Annex 1

List of Participants

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Annex 2

SRBTW(14)2

Agenda

1. Opening of the meeting
2. Nomination of a Rapporteur
3. Adoption of the agenda
4. Consideration of the Terms of Reference, ICR(14)11
5. Development of inventories of ongoing & planned marine telemetry studies (ToR 1-3)
   a. Atlantic salmon
   b. Other species in areas of the North Atlantic frequented by salmon
   c. Collation and presentation of data
6. Identification of the most suitable areas for new collaborative telemetry studies (ToR 4 & 7)
   a. North American Commission area
   b. North-East Atlantic Commission area
   c. West Greenland Commission area
7. Identification of strategic partners and appropriate linkages to existing and planned tracking programmes, etc. (ToR 5 & 6)
8. Next Steps
   a. Recommendations for the development of detailed plans for projects in selected areas and approaches to fund-raising (ToR 8)
   b. Future role of the IASRB
9. Any other business
10. Report of the Meeting
11. Close of the Meeting

Annex 3

SRBTW(14)3

Drifters and BioProbes: Options for detecting acoustically tagged fish in large geographic areas (North American and/or North-East Atlantic Commissions)

Background

Atlantic salmon are assumed to undertake directed movements at sea that take them over a large spatial domain over an extended period of time. Line arrays for detecting the movement of telemetry marked animals and to estimate apparent 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 uni-directional (see various ref papers). The probabilities of detection of these linear arrays are quite high because of close spacing of a limited number of receivers. Detection and apparent survival probabilities can be estimated using mark and recapture models for a sequence of arrays traversed by animals in a sequential manner, up to the last array location. Linear arrays with proximal receiver deployments that provide a near 100% probability of detection if the fish passes within the receiver field can provide robust information on numbers of animals within or passing through the line but the spatial and temporal coverage is limited to the spatial coverage of the line and the limited time the animals are in the range of the receivers.

Moving the detection infrastructure in areas in which animals can disperse over much broader areas is a challenge for line arrays because of their narrow spatial coverage and the short time period during which acoustically tagged animals may be in the vicinity of any of the receivers in the array.

Skeletal grid deployments

To address the challenge of monitoring large areas, a spatially broad grid of receivers would be deployed, for which individually there would be a low probability of detection of tagged animals in the grid field but for which the tagged animal would be in the overall potential field of detection for an extended period of time. Because the animal is constantly transmitting its identification and is moving within the receiver field, the probabilities of detection become a multiple of the instantaneous individual probability detections and the time the animal is in the detection field. Even with very low probabilities of detections at individual receivers, the combination of constant id transmission, cumulative time within the receiver field and movement of the animal within the field can produce a high number of detections. In addition, the movements of animals, including swimming speeds and other migration characteristics, can be characterized. Loss rates based on intervals of time can also be calculated (but not loss rates and location at the same time?).

For example, if a project has access to 400 receivers for deployment in the Labrador Sea with which to answer questions on migration behavior and apparent survivals, the choice is whether to establish a few fixed linear arrays with high probabilities of detection of fish that are in the range of the line (space and time) or to establish a grid of widely spaced receivers with low probabilities of detection of an animal but for which the animal has an extended residence time within the spatial area of the grid.

For a grid of 400 receivers spaced 50 km apart, the spatial domain would be 1000 km by 1000 km, an area that should contain salmon post-smolts over a period of ten weeks or more (at 25 km

per day based on 1 body length per second, mean length of 30 cm). Placing receivers 50 km apart (at corners of a square grid), and assuming a tagged fish is detectable if it passes within 500 m of a receiver, then the probability of a tagged fish being detected when the tag transmits is about 0.8% (500/50000 * pi/4). For simplicity, we will assume that the probability of a tagged animal being detected on a given day is this value of 0.8%. If the animal lives for seven days and remains within the domain of the grid, then the probability of detecting it at least once during the week is 5.4%. If 100 animals move into the grid domain on day zero, the expected number of detections registered over the seven day period is:

val2.5pc	**median**	**val97.5pc**
2	7	12

If 200 tagged animals move into the grid domain on day zero, the expected number of detections over seven days will be:

val2.5pc	**median**	**val97.5pc**
7.0	13.0	21.0

If fish die at a rate of 10% per week, then the expected number of detections per week from 100 fish would be:

week	**val2.5pc**	**median**	**val97.5pc**
2	2	6	11
3	2	5	10
4	1	5	10
5	1	4	9
6	1	4	8

For a starting pool of 200 tags, the expected number of detections would be:

	mean	sd	MC_error	val2.5pc	median	val97.5pc
d[2]	12.06	3.375	0.03373	6	12	19
d[3]	10.83	3.233	0.03144	5	11	18
d[4]	9.779	3.028	0.03055	4	10	16
d[5]	8.835	2.884	0.02893	4	9	15
d[6]	7.861	2.78	0.02815	3	8	14
d[7]	7.191	2.655	0.02682	2	7	13
d[8]	6.383	2.474	0.02377	2	6	12
d[9]	5.773	2.358	0.02589	2	6	11
d[10]	5.186	2.283	0.02236	1	5	10

The expected detections would be higher than this, as the probability of the fish being detected on any given day is the product of the number of transmissions in a 24 hour period and the rate of movement of the animal within the receiver grid, this will need to be modeled to determine optimal tag numbers.

This grid design should provide data to estimate the probability of detection (for the grid overall) and the apparent number of animals alive per given time step (daily, weekly, etc). It would also provide data on location of animals within the grid per given time step.

<u>Options for deploying grids</u>

- Bottom deployments could be undertaken but bathymetry constraints (depth) may limit their capacity to detect salmon in the upper portion of the water column.

- A grid of floating / drifter / high flyer receivers could be deployed in the area of interest. To maintain the grid domain structure, low drag drifters would be best. VR2 logger and satellite beacons could be used to track and retrieve the drifters for data download:

  -requirements: drifter / high flyers ~ $2500 per unit ($1000 for satellite deployed high flyer, $1500 for VR2) and radio tag for aiding location of units $???
  - vessel for deployment: opportunistic deployment on established surveys or charter vessel for deployment and retrieval
  - oceanographers to model potential movements of drifters and to assist in study design
  - pilot study:
    - in Gulf of St. Lawrence (mid-June to Mid-July), twelve drifters. Potential lead: DFO
    - in Gulf of Maine (end of May to mid-July), twelve drifters. Potential lead: NOAA
  - period of interest for Labrador Sea: early July to mid-September

- bioprobes. deployment of satellite transmitters linked to VR2W on grey seals in the southern Gulf of St. Lawrence
  - as with the drifters but actively move in the potential domain of salmon post-smolts during migration to Labrador Sea
  - $6000 per bioprobe
  - pilot study: six bioprobes in southern Gulf of St. Lawrence
  - dates: mid-June + for 11 months

- Potential linkages/partners
  - In southern Gulf of St. Lawrence, linkages with tracking of Atlantic cod to study interactions with grey seals, tracking of bluefin tuna (?), possibly American eel and striped bass

- Funding options
  - DFO inhouse research envelopes (International Governance Strategy, Strategic Program for Ecosystem Research and Assessment (SPERA))
  - NGO Atlantic Salmon Conservation Fund

- Ballpark budget/cost
  - $2500 per drifter X 12 per pilot area = $30,000 for capital
  - DFO southern Gulf research vessel Perley (4 days to deploy, 4 days to retrieve)
  - DFO Teleost September multi-species survey to recover drifters

    - in Gulf of Maine (end of May to mid-July), twelve drifter. Potential lead: NOAA

Annex 4

SRBTW(14)4

New Receiver Lines/Arrays/Grids (North American Commission Area)

Hypothesis/question:

- There have been major advances in our understanding of the marine ecology of emigrating post-smolts from North American rivers with the development of acoustic tagging and tracking technology. Starting in the mid-1990's, individual researchers began deploying small numbers of acoustic receivers in freshwater, estuarine and coastal environments. Coupled with these efforts was in-river monitoring efforts for Atlantic salmon, where emigrating smolts were captured, tagged and released. The tag emitted an ultrasonic pinger which was detectable by these receivers, thereby allowing for the monitoring of emigrating smolts/post-smolts through riverine and coastal environments. Technological advances and increased collaboration between researchers allowed for the development of larger projects tracking Atlantic salmon from multiple rivers as well as other marine species. With the establishment of the Ocean Tracking Network and the continued advances in these monitoring programs, acoustic receiver arrays now extend across much of North American range of Atlantic salmon and large numbers of detections are being recorded for Atlantic salmon hundreds of kilometres away from their natal rivers.
- Even given these advances, our ability to track migrating Atlantic salmon is somewhat limited and additional receiver detection points would greatly advance our understanding of the marine phase of Atlantic salmon. Additional receiver arrays at key locations 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 below, each addressing a specific aim and information need, but other locations could also be considered:

1. Passamaquoddy/Cobscook Bay arrays

    a. Installation of estuarine array(s) and utilization of platforms of opportunity (e.g. salmon net pen moorings (active and fallow locations), navigational buoys, commercial fishers etc.) within the Bay of Fundy/Passamaquoddy Bay/Cobscook Bay area would provide the necessary infrastructure for increasing the spatial distribution of tagged migrating Atlantic salmon within North America and would provide opportunities for investigating the causes of early marine mortality for an Endangered southern Canadian population.

2. Strait of Belle Isle triangular array

    a. A triangular array deployed offshore and to the east of the Strait of Belle Isle would allow for more robust mortality estimates for fish migrating through the Gulf of St Lawrence and would provide information on the initial Labrador Sea migration dynamics.

3. Strait of Belle Isle grid

    a. A gridded array of receivers deployed offshore and to the east of the Strait of Belle Isle would allow for more robust mortality estimates for fish

migrating through the Gulf of St Lawrence and would provide information on the initial Labrador Sea migration dynamics. The gridded array would provide increased spatial coverage, increased temporal coverage, but decreased detection efficiency.

4. Newfoundland array

a. A receiver array off the southeastern coast of Newfoundland, across the Grand Banks, would provide a natural extension of the Ocean Tracking Network Halifax array. This array would likely intercept migrating Atlantic salmon from the southern North American population or salmon that exit the Gulf of Saint Lawrence via the Cabot Strait. This array would allow for more robust estimates of mortality for salmon populations migrating from southern North American to the Labrador Sea while also providing information on the initial Labrador Sea migration dynamics.

Potential leads

- Atlantic Salmon Federation, NOAA Fisheries Northeast Fisheries Science Center, Department of Fisheries and Oceans, and Ocean Tracking Network

Equipment/support needs

- Passamaquoddy/Cobscook Bay arrays
  - Acoustic tags (St John River) – 300 (or more) *$400 = $120K/annum
  - Receivers: 50 *$1.5k = $75k
  - Deployment support
  - Incidentals * $2k/annum
- Strait of Belle Isle triangular array
  - VR2W Receivers – 1.5K (VR2) * 60 = $90k OR VR4s?
  - Deployment equipment - $100 *60 = $6k
  - Vessel/deployment –10K (5K deploy and 5K retrieve)/annum
- Strait of Belle Isle grid
  - Needs further examination (VR4 vs VR2W)
- Newfoundland array
  - Needs further examination (VR4 vs VR2W)

Equipment manufactures

- Vemco

Potential timelines

- Proposals, 2016
- Field work, 2017
- Duration, 10 years

Potential linkages/partners

- Any and all researchers with OTN NW Atl. detections

Funding options

-

Ballpark budget/cost

- Passamaquoddy/Cobscook Bay arrays
  - Capital: $100k
- Strait of Belle Isle triangular array
  - VR4 approach
    - unknown
  - VR2W approach
    - Initially $100k, then $25k/annum
- Strait of Belle Isle grid
  - VR4 approach
    - unknown
  - VR2W approach
    - Initially $100k, then $25k/annum
- Newfoundland array
    - VR4 or VR2W approach needs tbd
- Tags per annum: >$120K
- Incidentals per annum: $5k
- Travel/deployment costs per annum: $10k
- Personnel (In kind?)

Annex 5

SRBTW(14)5

Platforms of Opportunity in the North American Commission area: Stationary Platforms of Opportunity Receiver Exchange (SPORE)

Hypothesis/question:
Broad spatial coverage of Atlantic salmon marine habitat is needed to better understand migration time/space elements and to study variability in marine survival. Because dedicated receiver lines and grids are expensive to develop and maintain, a broad distribution of receivers deployed on opportunistic ocean assets can provide useful baseline acoustic monitoring data that is associated with collection of environmental monitoring (oceanography and weather buoys) and offshore commercial enterprises (fishing, aquaculture, offshore energy, etc.). Tier 1 monitoring using VR2W-type equipment with annual or semi-annual equipment exchange. Tier 2 monitoring using Cabled VR-4/VR-2 monitoring for real-time data monitoring. These associations of fish location data with environmental and commercial enterprise data provide an opportunity to exchange information and expertise with oceanographers and others to better understand seasonal salmon distributions in changing oceans.

Potential Lead:
NOAA Fisheries Northeast Fisheries Science Center, Department of Fisheries and Oceans, Atlantic Salmon Federation, and Ocean Tracking Network

Equipment/support needs:
- VR2W (30, 200)
- Cabled VR-4 (3,10)
- Sentinel Tags (30, 50)
- Cooperative Development of Mounting Systems Custom to Partners Gear
- 4 months data management support, equipment distribution, and troubleshooting

Equipment manufacturers:
Vemco, University of Maine Oceans Lab, Local Machine Shop

Potential timelines
- Field work – Seasonal 2015 (Phase I); 2016-2019 (Phase II)
- Duration – 2015 +, long-term monitoring

Potential linkages/partners: Integrated Ocean Observing System (IOOS); Atlantic Cooperative Telemetry Network (ACT), Offshore energy developers, Fishers and Aquaculture, Coast Guard, Other fish research community -sturgeon, eel, and shark researchers (Goulette *et al*. 2014).

Funding options:
- Baseline – Cooperative with NOAA-F NEFSC and University of Maine Ocean Observing System (10 locations) since 2005.
- Phase I – expand tier 1 monitoring to 5 additional NOAA stations in Gulf of Maine and 15 total in Gulf of St. Lawrence. Establish tier 2 monitoring on 3 Gulf of Maine Stations. Total of 30 stations and 3 real-time.
- Phase II – based on results of North Atlantic wide inventory consult with Salmon Telemetry Group to prioritize coverage and foster new partnerships to expand coverage to 50-75

stations in both the Gulf of Maine and St. Lawrence and 50 stations on the continental shelf in the vicinity of the Strait of Belle Isle. Total of 200 stations and 10 real-time.

Ballpark budget/cost:

- Phase I – $83K
- Phase II - $477K purchase year, $109K-$125 thereafter

Annex 6

SRBTW(14)6

North American Commission kelt satellite tagging

Hypothesis/question

- Iteroparity is an important life history trait of Atlantic salmon. Individuals can contribute to future generations via spawning contributions in multiple years, thereby increasing both individual and population level productivity. These repeat spawners were historically an important component for many North American Atlantic salmon populations. Repeat spawners are more efficient spawners due to past experiences and are typically larger than maiden spawners and, therefore, more fecund. For many North American populations, the repeat spawner component has been lost or significantly reduced due to a variety of anthropogenic impacts (e.g. dams) and increased marine mortality.

- Pop-off Satellite Archival Tags (PSATS) have recently been used to study the migration of post-spawned Atlantic salmon kelts in both North America and Europe. This technology offers the ability to provide information on stock-specific migration routes, behavior and mortality of post-spawned Atlantic salmon kelts. When combined with results from ongoing post-smolt telemetry projects, insights may also be gained into the commonalities of kelt and post-smolt migration patterns. Data may also be obtained on adult mortality rates at sea.

Potential leads

- Atlantic Salmon Federation, NOAA Fisheries Northeast Fisheries Science Center, Miramichi Salmon Association, Department of Fisheries and Oceans, and the Restigouche Watershed Management Council

Equipment/support needs

- Rivers (n=4) – Penobscot, Miramichi, Restigouche, St John Rivers
- Satellite archive tags – $4K * 10 per river = $160K
- Acoustic tags - $400 * 10 = 16K
- Misc equipment – $2K

Equipment manufactures

- Vemco
- Microwave telemetry/Wildlife Computers

Potential timelines

- Miramichi operational since 2012
- Proposals, 2015
- Field work, 2016
- Duration, 3 years

Potential linkages/partners

- European colleagues to standardized methods

Funding options

- In-kind salary support
- New Brunswick Wildlife Trust Fund
- Atlantic Salmon Conservation Fund
- *National Science Foundation*
- Pew Charitable Trusts
- NOAA/NMFS International Science
- Atlantic Salmon Federation
- NASCO Parties
- Others?

Ballpark budget/cost

- $175K per year (scalable)

Annex 7

SRBTW(14)7

Generic Index River Sites in the North-East Atlantic Commission area

Aim

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 for each site to:

1. Quantify total sea survival, from leaving the river to returning to river
2. Quantify where the mortalities occur by separating total sea mortality into mortality in 1) river mouth/estuary, 2) near coastal area, and 3) remaining stay at sea.
3. Quantify variation in mortality among years.
4. Analyze critical periods for mortality and possible causes for mortality.

By this provide scientists/managers/NASCO with quantitative mortality estimates and in addition be able to identify how large the mortality is in coastal areas where it is possible to implement management measures (dependent on the causes of mortality), and how large the mortality is in ocean areas, where management measures are more difficult to implement. This will both facilitate stock assessment models - and identification, implementation and evaluation of quantitative effects of management measures.

Methods

1. *Quantify total sea survival, from leaving the river to returning to river*

   Use for instance PIT-based systems with antennas recording all tagged fish returning (tagged with PIT-tags as pre-smolts or smolts), wolf traps or other total traps in combination with individual tagging of fish, mark recapture methods or other possible methods to record individual-based survival.

2. *Quantify where the mortalities occur by separating total sea mortality into mortality 1) in river mouth/estuary, 2) near coastal area and 3) during remaining stay at sea.*

   Tag smolts with acoustic tags and record their survival through river mouths and in near coastal areas by deploying arrays of acoustic receivers in river mouths/estuaries and as far out on the coast as possible (outer fjords, sea lochs, outer bays, "Irish lines", "Scottish lines", line between Denmark and Norway… etc.). Preferably, lines with full coverage so all tagged fish passing are recorded, or double lines so recording efficiency of inner line can be estimated.

   Acoustic arrays can be deployed at sites where several index rivers are covered by the same arrays (for instance "Irish lines", "Scottish lines", Trondheimsfjord area in Norway covering 10-20 important salmon rivers, including Gaula, Orkla, Nidelva, Stjørdalselva, which are among the largest Norwegian salmon rivers). If a fjord site in Norway is selected, arrays close to the coast north and south of the site can be deployed to record migration direction of the post-smolts after leaving the fjord

   It will be a challenge to separate between live smolts and predators. For example, depth tags or other methods can be used to identify behavioural signatures that can be used to distinguish between live smolts and tags in potential predators.

Lice-induced mortality should preferably be identified in index rivers in areas with salmon farming to be able to identify "general ocean mortality" from salmon lice induced mortality. This can be done by large-scale experiments in the same areas comparing groups of fish protected against salmon lice with chemical treatment and control groups. The main aim in this respect is not to focus on aquaculture, but this is needed to be able to identify general ocean mortality from anthropogenic mortality in coastal areas. (The post-smolts are infested by salmon lice in the coastal areas, but the lice has usually not developed to stages causing mortality before the salmon have migrated into the ocean areas).

4. *Analyze critical periods for mortality and possible causes for mortality.*

   Use data collected under 1. and 2. To compare 1-, 2- and 3-sea-winter salmon for evaluation of mortality in the first, second and third year at sea. Use data collected at tagging (length, mass, smolt quality, age etc.) to analyse which were the fish that survived and which were the fish that died – are there any characteristics/patterns that can be used to identify causes for mortality (coastal mortality and ocean mortality separately)?

   Are there any effects of environmental factors on coastal and ocean survival? Water discharge in river, coastal/ocean temperatures, salinities etc.?

   Compare results among rivers in cases where there are several rivers within the same index site.

   Use scale samples from returning fish (collected by using traps, from fisheries etc.) in the same rivers for possible analyses of when during the ocean migration growth was slow/fast to try to evaluate critical periods. Early post-smolt phase in ocean potentially critical period?

   Compare similarities and differences in results between the index sites in different geographical areas, and knowledge on which areas fish from the different sites/geographical areas use in the ocean, to discuss possible causes for mortalities (do sites with salmon using different ocean areas show similar or different patterns, for instance).

   If total traps are used or where recaptures are high, it is also possible to tag a sub-sample of fish from the same rivers (smolts or kelts?) with DST-tags to get information on, for example, temperatures experienced during the ocean migration and migration routes/ocean feeding areas (based on light, depth, temperature).

Potential Leads
Kim Aarestrup

Equipment needs
1) Wolf traps or other total traps, PIT-tags and PIT antennas
2) Acoustic transmitters and receivers
3) Scale samples, other equipment to record smolt quality etc.

Manufactures

1) Oregon RFID, Biomark and others
2) Thelma, VEMCO, Lotek, others?
3) Different equipment

Potential timelines

Long-term study. Aim is to establish long-term data series with survival data.
BUT, will obtain results in the first study year that can be used and published (coastal data after a few months of field work, survival of one-sea winter after one year, two-sea-winter after two years etc.)

Other linkages/partners

Sites and salmon scientists in Ireland, Scotland, Norway, Denmark, other countries?

Funding options

National management authorities in different countries? Industry (hydropower, aquaculture)? Others?

Ballpark costs

€350 000 - €500 000, or more, per site per year

Annex 8

SRBTW(14)8

Malin Head to Islay Receiver Array (North-East Atlantic Commission area)

Hypothesis/question

- The development of large scale telemetry receiver arrays in North America has greatly advanced the understanding of Atlantic salmon early marine migration. These large receiver arrays have provided detection information for a large number of other species migrating through the areas of coverage as well. The development of similar 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 large number of United Kingdom and Irish Atlantic salmon stocks migrating through this area in addition to other marine species migrating in this area. Key questions to be addressed are:
  - What is the mortality of the early marine phase of Foyle and Irish Sea salmon?
  - What is the usage of the North Channel of the Irish Sea 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?

Potential leads

- Loughs Agency, Glasgow University and Queens University Belfast

Equipment/support needs

- 100 acoustic detectors with 600m range

Equipment manufactures

- Vemco, Lotek, Thelma, Biotel

Potential timelines

- Field work, 2016-2022
- Duration, 2016-2023

Potential linkages/partners

- Marine Scotland, Marine Institute, Agri-Food and Bioscience Institute, Inland fisheries Ireland, Rivers And Fisheries Trusts Of Scotland, Department of Culture, Arts and Leisure, and Department of Agriculture and Rural Development

Funding options

- INTERREG V

Ballpark budget/cost

- £2,000,000

Annex 9

SRBTW(14)9

North Sea Loose Array (North-East Atlantic Commission area)

Hypothesis/question:
Understanding of Atlantic salmon migration routes is needed to better understand behavior and timing of the migration as well as potentially sectioning the marine survival and identifying potential migration corridors. Because of scale, dedicated receiver lines and grids are expensive to develop and maintain. However, a broad distribution of receivers deployed on opportunistic ocean assets in the area between Scotland and Norway may provide useful for at least partial coverage of a relatively narrow area sectioning the North Sea from the Atlantic. Possible sites could be oceanography and weather buoys and particularly offshore commercial enterprises (fishing, aquaculture, offshore energy, etc.). Some of these will in addition to baseline acoustic monitoring data also offer collection of environmental monitoring. The aim is to use these opportunities to cover approximately 30 % of the area going from a rough line from Northern Scotland to Southern Norway using VR2W-type equipment with annual or semi-annual equipment exchange.

Potential Lead:
Someone in Scotland/Norway, and Ocean Tracking Network

Equipment/support needs:
- 160 VR2W
- Various Partners owning platforms, Marine institutes?
- Management support, equipment distribution, and troubleshooting

Equipment manufacturers:
Vemco, Others?

Potential timelines
- Field work – 2016-2019 at the earliest
- Duration – 2-10 years

Potential linkages/partners:
Energy companies, Military, OTN

Funding options:
- OTN
- EU project?
- Energy companies (INSITE project?)

Ballpark budget/cost:
- €400,000 (or more) NB: NO TAGGING

Annex 10

SRBTW(14)10

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

Testable hypotheses

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. The utility of using smolt migration models for designing large scale telemetry monitoring projects should be considered further. Currently tagged fish are only being recorded in areas local to their tagging, i.e. at the mouths of estuaries or fjord systems. The next time they are encountered is on their return migration. We do not currently know where the subsequent mortality occurs. By setting up acoustic monitoring lines further along the postulated routes of migration, and extending from those, we should be able to determine what proportion die en route, and what proportion in the feeding/growing areas.

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. Also, some consideration could be given to investigating the availability of existing platforms along the shelf edge to mount detectors (e.g. gas and oil platforms such as Corrib Gas, Schiehallion etc).

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.

One risk of assuming that the fish pass through such restricted 'gateways' is that they may go wider, i.e. around our array of glider transect, missed by the detectors and then incorrectly assigned as having died prior to reaching the detector array or transect. In response to this, we should consider deployment of a minimum of two gliders. One would be deployed in the area where the models suggest the most likely migration route to be. Simultaneously, the second glider would cover a much wider transect, ideally covering an entire ocean "gap" e.g. between Ireland

and Scotland, to cover all fish migrating up through the Irish Sea, or between Shetland and Faroe, with the first glider focusing on the shelf edge region.

Potential project leaders
Spain, France, Ireland (Marine Institute), Scotland (Marine Scotland), Norway (IMR).

Equipment and support needs
Information was presented indicating that the OTN had recently successfully deployed AUVs (Wave Gliders®) along the Halifax acoustic receiver line, which runs from the shore to approximately 250 km offshore, upload data from bottom-mounted acoustic receivers and then transmit that data back to shore via satellite. Using AUVs to download receiver data would result in significant cost savings for managing these types of programmes as expensive ship time is no longer required to download data. AUVs can also serve as mobile receivers listening for tagged animals.

Equipment manufacturers
Liquid Technologies produce the "Waveglider". There may be other manufacturers.

Potential timelines for field work and duration
Essentially the deployment of AUVs (e.g. wave gliders) would be carried out to coincide with model predicted location of stocks from specific areas between April and June (West coast of Ireland), June - July (west of Scotland) and August - October (west of Norway in the Norwegian sea). Could start rapidly given commitment for some small requirement for shiptime to deploy AUVs. Carried out over three years all three locations above could be well covered.

Potential linkages and partners
There are good opportunities for linkages between the Marine academic and technical institutes from Spain, France, Ireland, UK and Norway making this an attractive international proposal.

Funding options
National research/management authorities in different countries
Industry (hydropower, aquaculture)
EU – Interreg.
EU funds in 2015 in relation to Arctic, Blue Growth, Climate and TransAtlantic calls.
Pew Charitable Trust and other philanthropic organizations

Ball park budget costs
Offshore array of receivers - North West of Ireland on shelf – €100K
Acoustic Tags – assume these will come as part of the nearshore tracking initiatives.
Deployment could be included with ship costs indicated below.
Costs of personnel – Could also be linked with personnel costs indicated below for AUV tracking.

Wave glider with acoustic receiver technology– Possibly consider two gliders – use one on a short track to test highway – other covers longer track. Refine tracks with more info
Acoustic Tags – assume these will come from nearshore tracking initiatives.

Assume three tracking lines
North West Ireland (Southern UK, Spain, France, Ireland)
Scottish/Irish line
Norwegian sea line (or lines)

Cost per wave glider (Liquid Technologies web page) = $300,000 US, (old version of glider is only $175, 0000)
Probability of detection analysis based on ranges, speeds, directions etc.
10km bands probability will have a good detection range.
Costs of personnel – €70k over three years.
Costs for marine support – Approx €80K (10 sea days @8K per day)

Annex 11

SRBTW(14)11

North-East Atlantic Commission kelt satellite tagging

Hypothesis/question

- Atlantic salmon kelts from different rivers make migrations 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 (~ variable year to year). The use of satellite tags on kelts will allow researchers to address the following questions:
  - 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

Potential leads

-

Equipment/support needs

- Three or four sites, PSAT/ MRPAT/ SURV 50 individuals per site during two year tagging programme. €1m equipment.
- Two sites, one year, 50 DSTs at each site. Expectation of 10% recovery. ~€300k
- Logistics of tagging programme are considerable, half year of dedicated time per site per year (two people for three months)…4y in total. ~€300,000 or more
- Laboratory work ~£1m
- Analysis and assessment ~£1m

Equipment manufactures

- Platform agnostic, so Microwave, Wildlife, Vemco, etc. Within EU would require tendering in any event.

Potential timelines

- Proposal, 2015
- Field work start in 2016
- Duration, 5 years

Potential linkages/partners

- Consider as part of large multispecies ocean climate project a la CLIOTOP, TOPP or similar. Link to other large-scale ocean basin projects. Sharks (basking, porbeagle), whales, seals etc. Integration of pelagic/ mesopelagic.
- Linkages with work in Ireland, Norway, Sweden, Denmark, UK, North American partners and Greenland
- Linkages with post-smolt telemetry efforts

Funding options

- EU funds in 2015 in relation to Arctic, Blue Growth, Climate and TransAtlantic calls
- Pew charitable Trust and other philanthropic organizations

Ballpark budget/cost

- €4m and €6m per year (scalable)

Annex 12

SRBTW(14)12

Sub-adult satellite tagging at Faroes

Hypothesis/question:

- Atlantic salmon sub-adults from different populations mix on feeding areas around the Faroes. Historically, commercial fisheries exploited this resource and provided access to marine Atlantic salmon to researchers. The use of satellite tags on fish captured and released at the Faroe Island feedings areas, combined with genetic assignment techniques, will allow researchers to address the following questions:
  - Partitioning 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 area
  - Return/ predation rates and type
  - Migration dynamic linkages with oceanographic conditions

Potential leads

-

Equipment/support needs (per year)

- Two field seasons, PSAT/ MRPAT/ SURV 100 individuals per site during two year tagging programme. €1m equipment
- Tagging programme staffing ~€300k
- Analysis and assessment ~€1m

Equipment manufactures

- Platform agnostic, so Microwave, Wildlife, Vemco, etc.

Potential timelines

- Align to other efforts in NEAC/ NAC, so 2016 at earliest

Potential linkages/partners

- Align to other efforts in NEAC/ NAC, so 2016 at earliest.

Funding options

- International focused

Ballpark budget/cost

- €3m (estimated and scalable)

Annex 13

SRBTW(14)13

Adult satellite/acoustic tagging at Greenland

Hypothesis/question:

- While great advances in our understanding of mortality, dynamics and ecology of Atlantic salmon during their first year at sea have been made over the past few decades, very little is known about salmon during their second year at sea. The West Greenland Atlantic salmon stock complex is comprised of Atlantic salmon originating from both Europe and North America. During the summer and early fall, fish are in close proximity to the West Greenlandic coast. This provides an opportunity for researchers to access fish that have survived through one year at sea and are generally destined to return to natal rivers as two-sea winter maiden spawners. These two-sea winter maiden spawners are often a critical component of the spawning stock for many salmon population across the North Atlantic as they contribute a significant number of eggs given their larger size.
- Pop off Satellite Archival Tags (PSATS) have recently been used to study the migration of post-spawned Atlantic salmon kelts in both North America and Europe and have also been used on Atlantic salmon captured, tagged and released at Greenland. This technology, in combination with genetic assignment methods, offers the ability to provide information on stock-specific migration routes, behavior and mortality during the second year at sea.

Potential leads

- NOAA Fisheries Northeast Fisheries Science Center, Greenland Institute of Natural Resources, Atlantic Salmon Federation, Department of Fisheries and Oceans and other European partners and agencies

Equipment/support needs (per year)

- Satellite tags - $4K per *20 = $80K
- Argos fees ($1K) *20 = $20K
- Acoustic tags - $400 per *50 = 20K
- Travel to Greenland - $10K/per *2 = $20K
- Telemetry receivers – existing receivers + a few new receivers
- Rod/reel gear - $200
- Misc supplies – $2K

Equipment manufactures

- Vemco
- Microwave telemetry/Wildlife Computers

Potential timelines

- Proposal, 2015
- Field work, 2016
- Duration, 3 years

Potential linkages/partners

Funding options

- In-kind salary support
- NMFS International Science
- ASF
- NASCO Parties
- Others?

Ballpark budget/cost

- $150K per year (scalable)