Northeast Fisheries Science Center Reference Document 19-10

Current Status of Knowledge, Data, and Research Efforts on Atlantic Salmon at Greenland:

What Do We Have, What Do We Need, and What Should We Do Moving Forward?

by Timothy Sheehan

July 2019

Northeast Fisheries Science Center Reference Document 19-10

Current Status of Knowledge, Data, and Research Efforts on Atlantic Salmon at Greenland:

What Do We Have, What Do We Need, and What Should We Do Moving Forward?

by Timothy Sheehan

NOAA Fisheries, Northeast Fisheries Science Center,
166 Water Street, Woods Hole, MA 02543

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

July 2019

Northeast Fisheries Science Center Reference Documents

This document may be cited as:

Sheehan T. 2019. Current status of knowledge, data, and research efforts on Atlantic salmon at Greenland: What do we have, what do we need, and what should we do moving forward? US Dept Commer, Northeast Fish Sci Cent Ref Doc. 19-10; 89 p. Available from: http://www.nefsc.noaa.gov/publications/

BACKGROUND

The waters off the coast of West Greenland serve as an important summer feeding area for future maiden 2 sea-winter Atlantic salmon (*Salmo salar*) spawners originating both from Southern Europe and North America. During the early 1960s, a significant international fishery developed at West Greenland with reported landings approaching 3000 t in the early 1970s. Catches have generally declined since, and the fishery has been reduced to local-use only recreational and commercial harvests with reported landings ranging from 27.1 - 57.9 t from 2010-2016.

Annual sampling of the West Greenland Atlantic salmon fishery has occurred since 1968 (with the exception of 1993-1994) to the present, and results from this monitoring program provide critical information used by the International Council for the Exploration of the Sea (ICES) Working Group on North Atlantic Salmon (WGNAS) in support of their annual Atlantic salmon stock assessments. Results from these assessments are used as a basis for providing catch advice for the West Greenland fishery to the North Atlantic Salmon Conservation Organization (NASCO) West Greenland Commission. The resulting database and associated samples represent a rich resource of information that can be used to evaluate the marine dynamics and ecosystem drivers of Atlantic salmon marine survival for these one-sea-winter (1SW) non-maturing fish. Despite the importance of this program, the results from these studies have not been widely communicated nor completely understood, even after decades of research. In addition, numerous other studies have also been conducted in association with the sampling program and suffer from the same relative obscurity.

Assessment of the effects of the West Greenland salmon fishery on homewater stocks and fisheries requires biological characteristics data from the exploited population as well as estimation of the proportion of the catch that is North American and European in origin. Presently, there are approximately 60K records detailing sampling date, location (NAFO Division), size (mainly fork length [cm)] and gutted weight [kg]), river/sea age, presence of spawning marks, and continent of origin for the sampled individuals. In addition, individual scale and tissue samples (tissue samples since 1999) are also available for the sampled individuals. These data and samples provide an archive of information that can inform future investigations on the health and status of the Atlantic salmon West Greenland stock complex over time. This archive can also be used to inform future investigations on the impact of a changing climate on the productivity of Atlantic salmon stocks in the North Atlantic.

The sampling approach has evolved over time. From 1969 through 1981, random samples were collected from research vessels fishing gillnets of similar mesh size and type as used in the commercial fishery. From 1982-1997 and again in 2001, samples were not randomly taken, but rather were obtained from commercial landings, which were presorted by weight category. From 1998 to 2000 and again from 2002 through to the present, random samples were collected from local markets, other vendors, and factories from individual communities where Atlantic salmon are being landed. Given the varied sampling methodologies, care should be used when interpreting the resulting data sets through time.

Given the constraints of poor marine survival on stocks from North America and Southern Europe, the importance of this life history type to the overall productivity of these stocks, and the difficulty and associated expense of sampling Atlantic salmon in the ocean, the West Greenland fishery sampling program provides an excellent opportunity to conduct studies that further our understanding of this critical life stage. Before initiating future studies, however, it is prudent to review the past and ongoing studies to inform the development of an efficient future research plan based on data needs and gaps. It is also important to review the current sampling plan to evaluate if improvements can be made to maximize the efficiency of the effort. Finally, it is also important to develop protocols for historic data and sample use to ensure their availability into the future, as many new sampling techniques are sometimes destructive. If access is not properly managed, these important data resources could be lost.

To address these issues and questions, a proposal to host a workshop was developed with 2 primary objectives:

- Review the past/ongoing studies on the West Greenland stock complex to inform future research based on data needs/gaps; and
- Recommend protocols for historic data and sample use.

Specific objectives were also developed to further shape the workshop:

1. Review historical/current state of knowledge (literature review and data inventory) of Atlantic salmon at the summer feeding area off the coast of West Greenland;
2. review current research efforts on Atlantic salmon at the summer feeding area off the coast of West Greenland;
3. review inventory of archived databases (sampling database, genetic assignment database, etc.) and samples (scales, tissue, etc.) available from Atlantic salmon collected at the summer feeding area of the coast of West Greenland;
4. compile future data needs and gaps;
5. develop short list of research themes/projects to address future data needs and gaps;
6. develop recommendations for improving future fishery sampling efforts; and
7. develop protocols for providing access to database(s) and archived samples for collaborating researchers.

The Atlantic Salmon Research Joint Venture (ASRJV) provided funding and assistance to support the workshop. The ASRJV is a collaborative research partnership with the objective of promoting and facilitating collaborative research to address important and urgent knowledge gaps and threats affecting North American wild Atlantic salmon at all life-history stages and throughout its geographic range. This newly formed partnership aims to bring together experts from provincial agencies, scientific institutes, indigenous groups, non-government organizations, academic institutions, and other stakeholders, including NOAA Fisheries Service, to better understand and manage North American Atlantic salmon stocks. As a partner in the ASRJV, the Fisheries and Oceans Canada (DFO) annually provides funds for ASRJV partner projects through the Oceans and Freshwater Science Contribution Program.

The workshop was held from December 7-9, 2017 at the Cambridge Suites Hotel Halifax, Halifax, Nova Scotia, Canada. A total of 18 attendees from North America and Europe participated (ANNEX 1). Workshop participants covered a wide range of experience and interests with the West Greenland sampling program. Some participants are currently involved in the sampling program; some individuals have been involved in research projects utilizing the data and samples collected; and some individuals were selected to provide advice on best future use of collected data and samples as well as future data needs, gaps, and research plans.

The workshop agenda (ANNEX 2) was organized to address each of the specific objectives in turn. The remaining report will provide an overview of discussions, conclusions, and recommendations which occurred under each objective.

RECOMMENDATIONS

The participants developed a number of recommendations during the course of the workshop. These are summarized below in no particular order of priority. Further detail and context about each recommendation can be found within the body of this report.

- Further effort should be focused on understanding the potential biases caused by the evolution of the sampling program from research surveys, to nonrandom sampling at factories, to random sampling from local markets and factories within individual communities.
- Reanalysis of historic survey and sampling catch data is warranted.
- Region of Origin (ROO) genomic assignments should be conducted on various archived sample sets (e.g., historical Labrador Sea survey samples).
- Consideration should be given to organizing a joint workshop between Atlantic salmon researchers and oceanographers to assist in compiling and understanding the numerous environmental and oceanographic datasets needed to support future collaborative Atlantic salmon investigations.
- The ICES WGNAS sampling tables do not match the reanalysis of the database, and efforts should be made to rectify discrepancies. All changes should be clearly identified and explained within the ICES WGNAS report. Suggested improvements to the sampling database should be incorporated.
- A comprehensive inventory of the archive scale samples should be conducted.
- Efforts should be undertaken to harmonize the method and location of archived tissue samples for genetic analysis.
- The current infrastructure and process for maintaining the sampling database is adequate for the current needs and should be maintained.
- Efforts to advertise the existence of the sampling database and archive samples via poster/oral presentations and a peer-reviewed manuscript should be pursued.
- There was support for further research investigating the impacts of changing energy dynamics of marine phase Atlantic salmon and their prey.
- There was support for increased telemetry-based investigations into the marine migration dynamics using Atlantic salmon available at Greenland (e.g., acoustic, Pop-off Archival Satellite Tag [PSAT], and the new ROAM [RAFOS Oceanic Acoustic Monitoring] telemetry approaches).
- Consideration should be given to organizing a workshop or a series of conference calls to outline the current state of knowledge of stable isotopes and their ability to further our understanding on Atlantic salmon marine dynamics. Consideration should also be given to support the further refinement of the isoscape of the North Atlantic.
- Further engagement and participation by the Government of Greenland and the Greenland Institute of Natural Resources in the sampling program is warranted.
- Participants made a number of recommendations related to database management and storage, data access, and sample access for the future.

Literature Review and Data Inventory

A comprehensive review of the historical/current state of knowledge of Atlantic salmon at the summer feeding area off the coast of West Greenland was prepared and provided to all workshop participants (ANNEX 3). Tim Sheehan also provided an overview presentation, which generated a number of discussions. These discussions are summarized by topic below:

Sampling program biases

The sampling program has evolved over time. From 1969 through 1981, random samples were collected from research vessels that fished with gillnets offshore of similar mesh size and type as used in the commercial fishery. It was noted that some inshore sets were made during this time period, but the details of these were unavailable. From 1982-1997 and again in 2001, samples were not random, but rather obtained from commercial landings that were presorted by weight category. In 1998 through 2000 and again from 2002 through to the present, random samples were collected from local markets, other vendors, and factories from individual communities where Atlantic salmon were being landed. Concern was raised that this evolution could cause some biases (e.g., assuming biological characteristics data obtained from non-random sampling are representative of the entire harvest, assuming that all samples originated from inshore feeding areas for stable isotope studies). Given the varied sampling methodologies, care should be used when interpreting the resulting data, and year-specific sampling methodologies should be incorporated when interpreting results. To better interpret the nonrandom sampling effort, information on reported harvest by landings category (preferably on a daily basis) is needed to adjust, correct, and better understand any potential biases. Possibly the Greenland Institute of Natural Resources or past annual ICES WGNAS working papers describing the fishery may have the data required to complete this assessment. Further effort in this area is warranted.

As part of the process for preparing for this workshop, a preliminary assessment of the database, potential biases, and available information had been conducted and will provide a good starting point for furthering this effort (See Inventory of Archived Databases and Samples below).

Marine research biases

Participants of the workshop noted that our knowledge of the marine phase of Atlantic salmon is biased. As an example, reported temperature preferences are based on where fish have been captured in the past, which is determined by where we have surveyed or where fisheries are conducted. In contemporary surveys, we have caught fish in areas other than expected and at temperatures outside the reported preferred range based on historical surveys. It was suggested that reanalysis of the historical catch data may be warranted. The reanalysis would involve more sophisticated methods and datasets and focus on presence and absence of fish across time and space.

Results from previous sampling efforts may also be biased because of gear selectivity issues. While postsmolts may be able to make it to the coast of Greenland, gillnet-based sampling may not be an effective method for capturing them. Postsmolts may be capable of longer migration distances than previously thought since relatively few postsmolts have been sampled at Greenland over the years and postsmolts sampled in the Labrador Sea (Reddin and Short 1991) are known to have originated from Scottish rivers. It has also been shown that postsmolts originating from Southern Northeast Atlantic Commission are capable of migrating extensive distances into the Norwegian Sea over a relatively short time period (Mork et al. 2012)

Further region of origin analysis of historical samples captured in the Labrador Sea (e.g., Salmon at Sea [SALSEA] North America, Sheehan et al. 2012) is warranted to further our understanding of migration dynamics during the first year at sea.

Historical Region of Origin (ROO) analysis

Recent improvements in the development of genetic baselines for both North America (Bradbury et al. 2016) and European (Gilbey et al. 2017) stocks will allow for finer assignments of origin than previously possible. Bradbury et al. (2016) presented ROO analysis for North American samples from 1968, 1978, 1988, 1995, 1996, 1998, 2002-2006, and 2011-2014, although pre-1995 sample sizes were low. Analysis of a larger number of samples will allow for more robust estimates of origin. Analysis of European origin salmon sampled at Greenland (2002-2012) has been conducted against the GRAASP (Genetically-based Regional Assignment of Atlantic Salmon Protocol) baseline, which was developed through the SALSEA-Merge. It is expected that results from these studies will be published shortly. With the continual refinement of genetic baselines, assignment to the river-level for many stocks is still a possibility and is actively being pursued.

Important specific sample sets for ROO assignments:

- All SALSEA Greenland samples (~1200) should be reanalyzed against the single nucleotide polymorphism (SNP) panel for consistency
- Additional samples from the Faroe Island stock complex should be analyzed as they would be informative for both the European and North American stock complexes. These data would allow for a more informed understanding of the historic and potential future contribution of regional stock groupings from both North America and Europe to the Faroese fishery. Currently, ROO assignments are only available for 2 years. Northern North American stocks migrate to Greenland, southern North America stocks migrate to Greenland and the Faroes, northern European stocks migrate to the Faroes, and southern European stocks migrate to both the Faroes and Greenland. These migration dynamics may all be linked and related to glaciation processes, which warrant further in-depth analysis.
- All archived Labrador Sea tissue samples should be analyzed. ROO assignments from individuals collected during historic surveys will fill in knowledge gaps and support migration modelling coupled with environmental data. These updated migration models may further our understanding of the factors driving marine dynamics.

Oceanographic data

Comprehensive oceanographic and ecological datasets should be compiled and analyzed along with region-of-origin data to better understand the migration dynamics of Atlantic salmon stocks across the range. While this effort was outside the scope of this workshop, effort should be made to identify and compile relevant oceanographic and ecological datasets. Consideration should be given to holding a separate workshop to develop collaborations between oceanographers, geneticists, salmon biologists, and modelers to initiate this effort. The North Atlantic Ocean is a very dynamic area, and a comprehensive review of the oceanography of the system would be very useful to many future Atlantic salmon marine research efforts. If pursued, care should be taken with organizing the effort to be as inclusive as needed, but not to the point where the Atlantic salmon focus may be diluted. As an example, it would be important to include researchers working on other co-occurring species, but care should be taken to keep the workshop focus specifically on investigating and understanding Atlantic salmon marine dynamics. It was noted that some oceanographic datasets have been compiled and analyzed (Mills et al. 2013). These datasets are being expanded and incorporated into current studies (i.e., marine growth studies), but further work is required.

Workshop participants were made aware of a new research effort called "LabSea2020 – A new international cooperative research program in the Labrador Sea." The initiative is intended to be "bottom-up" and aims to link researchers and research initiatives with shared interest in the region. Contacts for the effort are Doug Wallace (Douglas.Wallace@dal.ca) from Dalhousie University and Brad deYoung (bdeyoung@mun.ca) from Memorial University of Newfoundland. This effort may provide an opportunity to link Atlantic salmon researchers with oceanographers interested in the Labrador Sea. It was noted that this may be an appropriate avenue for possibility organizing a joint workshop between Atlantic salmon researchers and oceanographers to assist in compiling and understanding the numerous environmental and oceanographic datasets needed to support future collaborative Atlantic salmon investigations as outlined in recommendations above.

Current Research Efforts

A comprehensive review of current research efforts on Atlantic salmon at the summer feeding area off the coast of West Greenland was prepared and provided to all workshop participants (ANNEX 4). Tim Sheehan also provided an overview presentation from which a number of questions arose. These discussions summarized by topic below:

Lipid content investigations

Based on the results of a number of recent studies (Dixon et al. 2012; Mills et al. 2013; Renkawitz et al. 2015), a study was initiated to estimate the lipid content of Atlantic salmon captured at Greenland during 2009-2011. Additional samples were also collected in 2017, but they are outside of the scope of the 2009-2011 study. The possibility of lipid sample degradation over time was discussed and could be an issue, especially with some specific fatty acids. However, proper sample preservation techniques (double bagging sample to minimize dehydration, storage in scientific freezers, etc.) will minimize impacts. Using wet to dry weight ratios of samples is a cheap and easy alternative to lipid analysis once a suitable lipid to wet/dry weight ratio relationship has been established. To further strengthen the wet/dry weight relationship, efforts should be made to also analyze ash-free, dry weights as sometimes this can improve the relationship.

West Greenland scale investigations

When looking at marine growth from West Greenland scales, it would be beneficial to also compare marine growth datasets obtained from adult returns to homewaters of the same cohort to verify if any identified patterns continue through to the return stage while also looking for commonalities across river systems. An alternative hypothesis should also be considered: fish that migrate to Greenland do not make it home as adult returns, and maybe successful adult returns have come from other areas in the North Atlantic. Efforts are currently underway to obtain marine growth datasets from numerous North American and European rivers. Collaboration across studies was encouraged.

North Atlantic-wide genetic baseline

The development of a single North Atlantic salmon genetic baseline which could be used for ROO across the species range was discussed, and some progress was noted. Jeffery et al. (2018) reports on a regionwide assignment of Atlantic salmon captured at Greenland by using genome-wide single-nucleotide polymorphisms resulting in 20 reporting groups from North America and 7 from Europe. Collaboration continues with European research, and the new processing techniques are eliminating the need for standardization, making data sharing across the North Atlantic more feasible. Further progress on this topic is expected.

Genetic impacts of marine migration

There could be utility in characterizing the genetic impacts of the marine stage of Atlantic salmon. As an example, a genetic survey could be completed on different stages of migrations, such as cohorts of smolts from a few rivers/regions that contribute a significant proportion of the Greenland harvest; sub-adults harvested at Greenland that have been assigned to these same rivers/regions; and adult returns from those same rivers/regions and cohorts.

Greenlandic salmon (i.e., Kapisillit River) investigations

It was noted that there is currently interest in surveying select Greenland rivers for salmon presence and suitability for maintaining a self-sustaining population. Previous sampling work has been conducted on the Kapisillit River in 2005 and 2012, these data are currently being analyzed, and a scientific publication is in preparation. Any future sampling efforts should consider these previous studies. Further collaboration between the researchers involved is encouraged.

Sea lice investigations

Sea lice have been collected from salmon harvested at Greenland for a number of researchers since 2009. The question was raised as to whether the fish carried sea lice to Greenland or if they are being infected at Greenland. The consensus was that the fish sampled at Greenland have been infected with sea lice from the Greenland area, given the sea louse's life history. Again, communication with all researchers involved in sea lice investigations at Greenland is encouraged.

ROO and ICES WGNAS assessments

Considering there are presently insufficient resources to fund ROO analysis for all salmon sampled at Greenland, the ICES WGNAS will need to consider the data needs of their assessments, particularly into the future. The current subsampling approach for ROO is adequate to support ICES stock assessment subsequent catch advice efforts at a regional scale. However, to further understand the impact of the fishery on the smaller contributing stock, additional ROO is warranted. Additional data may be required to help identify potential spatial and temporal fishery management options requested by NASCO to protect weaker stocks.

Proper acknowledgement of collaborators

It was agreed that proper acknowledgement of the full list of collaborators is appropriate when presenting results from these long term datasets. The West Greenland sampling program and the ICES assessments are possible due to large expenditure of resources by many different countries and agencies over many decades.

Inventory of Archived Databases and Samples

A comprehensive review of the West Greenland sampling databases and archived samples (scale and tissue samples for genetics) was prepared and provided to all workshop participants (ANNEX 5). The database and scale samples are currently housed at the DFO Northwest Atlantic

Fisheries Centre in St John's Newfoundland, Canada. Similarly, a review of additional biological samples collected during the International Sampling Program at West Greenland was also prepared and provided to all workshop participants (ANNEX 6). These samples are from the more recent sampling years (1992-2016), and many were collected as part of the SALSEA Greenland program. Michelle Fitzsimmons and Tim Sheehan provided overview presentations of these topics. In addition, Niall Ó Maoiléidigh gave a presentation describing the *ICES Cooperative Research Report (CRR) No. 282, Fifty Years of Marine Tag Recoveries from Atlantic Salmon* (Ó Maoiléidigh et al. 2018). The CRR summarizes the work of 3 workshops hosted by ICES that compiled historic Atlantic salmon marine tag recoveries, provided some preliminary tag recovery summary statistics, and demonstrated the basis and concepts for future analysis of the tag recovery data. The discussions in response to these presentations are summarized by topic below.

Database discrepancies

In preparation for this workshop, a review of the archived databases and the tables produced by the ICES WGNAS was conducted, and several discrepancies were identified. Many of the ICES WGNAS tables are simply updated annually, and small discrepancies between the databases and the ICES WGNAS tables were identified during this review with no clear evidence of which numbers were correct. It was suggested that the ICES WGNAS tables should be updated to match the archive databases and that all changes should be clearly identified and explained within the ICES WGNAS report when the update is completed.

Sampling database additions

Several improvements to the West Greenland sampling database were suggested. First, the current databases should be archived and modernized into a single database. A unique identifier for each sample record should be created. Additional fields should be added to the database to compliment the continent of origin assignments (e.g., sample type analyzed [scale versus tissue], method used [scale pattern analysis, genetics]). In addition, the region-of-origin assignments should also be included along with the probability of assignment for assigned regional group and the method of assignment (i.e., a citation that describes the method and panel used for the assignment). Consideration should also be given when 2 different assignments are available. As an example there are 2 different ROO assignments available for the 2017 samples based on (1) the legacy 12 micro-satellites (Bradbury et al. 2016) and (2) the newly developed SNP panel (Jeffery et al. 2018). The 2018 ROO assignments will be conducted with SNPs only.

The general consensus was that results from any studies should be added to the main sampling database for future researchers to access. The data could be incorporated into the existing database or added as an independent flat file with unique sample IDs to link the results to the sampled individual. Potential additions to the database are results from recent stable isotope, otolith microchemistry, diet, and scale measurement investigations. For scale growth measurement studies, inclusion of an image of the scale with an appropriate scaler bar should also be considered. There are likely other datasets that should be included, and efforts should be undertaken to determine and accomplish this. It was also agreed that as a condition of any future data/sample access, all subsequent results should be provided for inclusion into the database.

It was recognized that modernization of the database will incur some cost, both in terms of funding and staff time. The group suggested that if a concrete plan with clear goals, objectives, and processes could be developed, the ASRJV may possibly consider funding such an effort given the importance of the information and the benefits that would be accrued. Efforts should be undertaken to pursue this further.

Archived scales

Archived scale samples are currently stored at DFO St John's, which is considered relatively secure and safe. There is a need for a proper inventory of which scale samples are archived compared to those listed within the database. As an example, for the 1968 collection the database states that 724 scale samples were collected, but there are 569 envelopes present. Further efforts will be required to identify why these discrepancies occur. It is possible that some archived scale samples have been removed in support of previous studies and were not returned to the archive. The consensus of the group is that efforts should be made to develop an accurate database, an accurate inventory, and a secure accounting system for future use. Accurately archiving samples was considered a high priority and likely would apply to other available samples, not just scale samples.

Archiving tissues samples for genetic assignments

Care should be taken when archiving tissue samples for future genetic analysis as there can be long-term storage issues resulting in tissue and DNA degradation. Long-term storage in EtOH is acceptable, although all vials must be checked every few years to ensure that the EtOH has not evaporated. A preferred option is storing extracted DNA in a -80 freezer, but there are resource implications with this method.

Historic tissue samples are stored at the USGS Leetown Science Center in West Virginia, USA (1995-2016) and the Bedford Institute of Oceanography in Halifax, Canada (beginning in 2017 with a small number of duplicate samples from various years prior). Consideration should be given to both harmonizing the storage method and the location of archived tissue samples originally collected for genetic analysis.

Current origin assignment

Continent of origin (COO) assignments for Atlantic salmon sampled at Greenland have been provided by the US Geological Service (USGS) since 1995. This work was originally funded by USGS but has been funded by NOAA Fisheries Service since the early 2000s. The ICES WGNAS have relied on genetic based COO assignments since 2002 (previous assignments were scale pattern analysis based). Starting in 2018, the COO and ROO assignments will be provided by DFO and supported by funding through the DFO International Governance Fund. Previous ROO assignments (Bradbury et al. 2016) were also supported by funding through the DFO International Governance Fund. The current DFO funding award is set to expire in 2020, and a new arrangement will need to be considered for COO/ROO assignments for 2021. Currently, it costs approximately $30K to process 1000 samples, excluding staff time. It was agreed that having a detailed cost estimate, including staff time, would be beneficial for the identification of future funding options.

Ovary samples

Ovary samples were collected during SALSEA Greenland and SALSEA North America. The samples have been processed, but not properly analyzed. The samples are currently stored at the DFO Gulf Fisheries Centre in Moncton.

SALSEA North America ROO

COO assignments have been provided for all SALSEA Greenland sampled fish (2009-2011). ROO assignments have been provided for the 2011 SALSEA Greenland sampled fish only. Considering the numerous other samples collected and analyzed for the SALSEA Greenland effort, it would be preferable to have ROO assignments for the remaining SALSEA Greenland samples (2009-2010). Genetic analysis has not been conducted for the SALSEA North America sampled fish. It would be beneficial to have ROO assignments for all sampled individuals. For the SALSEA North America samples, 2008 tissues can be obtained from archive frozen fish stored at the DFO Gulf Fisheries Centre in Moncton. It is unclear where the 2009 archived bodies are, and advice is being sought on this. Alternatively, workers at the University of Waterloo (Ontario, Canada) might have archived tissue samples that were collected for stable isotope analysis. Further effort to obtain and process these unanalyzed samples is desired.

Compilation of Future Data Needs and Gaps

Overarching question

What are the mechanisms behind the declines and variations in marine survival seen across the North Atlantic? We may not be able to study this directly, but we may be able to undertake specific studies that can help eliminate hypotheses. The current West Greenland program provides an excellent and existing opportunity to collect samples/data that, in concert with the historical West Greenland sampling database, will support investigations into the mechanisms behind the documented trends.

Co-occurring species and their ecosystem role

We have a good understanding of what salmon eat and what the co-occurring species complex is at West Greenland; however, our understanding of the dynamics and abundance of these co-occurring species is generally poor. These species are generally not commercially important, and therefore, formal assessments of their abundance is lacking. Dedicated prey surveys could be carried out in nearshore waters of Greenland in specific feeding areas for salmon.

Database hosting options

The database is currently housed at the DFO Northwest Atlantic Fisheries Centre in St. John's, Newfoundland and Labrador. This facility provides safe and secure archiving ability. Maintaining the database can be a resource intensive task, especially if future sample and data requests increase. Participants discussed a number of options for hosting the database, such as Access, SQL, an open source data hosting site, database options used at museums, biodiversity archiving tools (currently being explored by the Marine Institute in Ireland). There was discussion as to whether a new system would provide adequate benefits to justify the required investment (possibly fiscal implications, training, maintenance, learning curves, etc.). While it was noted that other jurisdictions (i.e., Ireland, France, UK (England & Wales), and Norway) with long-term scale/sample archive collections were currently investigating new approaches, it was decided that currently it is not worth the additional investment as the current database and process of managing are not too onerous. If progress is made in other jurisdictions in developing a better and more cost effective approach or the database increases in size or if requests for data or access to samples increase in the future, this option can be re-considered.

Advertising the existence of the West Greenland database as a resource

The participants agreed that the West Greenland sampling program has generated an extremely valuable database and archive sample collection that can be used to support future investigations. Its existence is well known to the participating scientists and the ICES WGNAS, but it is not known if researchers outside of these arenas are aware of it. Participants agreed that efforts should be made to advertise its existence further. One potential option would be to provide an oral or poster presentation at the International Year of the Salmon symposium being organized prior to the 2019 NASCO Meeting in Tromsø, Norway. Unfortunately, the agenda for the meeting had already been set, and an oral presentation was not possible.

Additionally, it was agreed that a peer reviewed publication describing the sampling program and resulting database should be compiled and submitted for publication. This paper should emphasize the importance of the sampling program to the management of wild Atlantic salmon range-wide (e.g., providing critical input data to stock assessment efforts, the importance of this life history type, providing access to fish for biological sampling) and also provide descriptions of the gear and sampling methods used over time.

Future sampling program options

Because of logistical issues, sampling does not usually occur early and late in the fishing season and no sampling occurs prior to or after the fishing season. While sampling before or after the fishery may not inform ICES WGNAS catch advice efforts, it may inform nonfishery ecological related questions.

A standardized sampling approach in a few locations used consistently throughout the entire fishing season would be beneficial to obtain information on stock use, growth, etc. As part of past West Greenland Sampling Agreements (NASCO 2015 [see WGC(15)21], NASCO 2016 [see WGC(16)9], NASCO 2017 [see WGC(17)8]) Denmark (in respect of Faroe Islands and Greenland) committed to ensuring that sampling the Nuuk fish market occurred on a weekly basis. Unfortunately, no samples have been taken to date.

Potential future studies

Diet

There was a desire for continued diet sampling of fish at Greenland, which is a possibility, but there are logistical and potentially financial challenges associated with this type of sampling (i.e., samplers must have access to fresh whole fish). The majority of fish landed at local markets are gutted prior to landings. In some cases, fishers may be willing to cooperate with an individual sampler by providing fish in the whole state, but often the fishers seek financial compensation. During the SALSEA Greenland sampling effort, NOAA Fisheries Service funded the purchase of the 1200 sampled fish. Financially there are costs associated with purchasing sampling equipment, shipping the samples from Greenland, and sample processing. Therefore, continuation of diet studies would require a new funding source.

Stable Isotopes

The use of compound-specific stable isotope analysis to assess food web changes over time was discussed as a potential tool to investigate the hypothesis that decreasing energy density of capelin (*Mallotus villosus*) in the Northwest Atlantic has negatively impacted marine salmon productivity (Renkawitz et al. 2015). It was suggested that analyzing samples obtained from the end of the fishery might be preferred as those tissue samples would have likely assimilated prey consumed while off the coast of Greenland. It was also suggested that for this study, and many other studies, a pilot project that analyzes a few samples from contrasting conditions would be a relatively quick means for assessing if a larger scale study is warranted and worth pursuing.

There was also interest in collecting samples from co-occurring local species (e.g., capelin, squid, themisto) from the waters off West Greenland for future stable isotope studies. Specifically, the samples would be used to further develop the isoscape of the region (i.e., the stable isotope profile in the waters off the coast of West Greenland). Having a robust isoscape profile of the entire North Atlantic may aid in future studies that compare stable isotope signatures from Atlantic salmon scales to varying stable isotope signatures on the Atlantic to develop migration models for individual salmon. Further collaboration between the stable isotope focused researchers and the Sampling Program Coordinator was encouraged.

- Otolith microchemistry
  - Otoliths can be used for a number of microchemistry-based studies (e.g., stable isotopes, micro-containments) as they provide a record of the chemical environments that individual salmon have been exposed to overtime. Recent work estimated stable oxygen isotope ($d^{18}O$) values via otolith micro-milling and mass spectrometry analysis as a proxy for marine temperatures experienced during the second summer at sea (Minke-Martin et al. 2015). Although not regularly collected, a low number of otoliths from West Greenland salmon are available for analysis. Additional samples could be collected in the future. The challenge is that collecting the otoliths often damages the fish, which may decrease its market value. However, arrangements could be made to enable this type of sampling.
- Genetics
  - See Genetic impacts of marine migration (above)
- Ecosystem data needs
  - See Oceanographic data (above)
- Region of Origin
  - See Historical ROO analysis (above)
- Outline of potential projects

The group decided not to pursue the development of potential projects during the meeting or develop a formal contact list of potential collaborators. Instead, the group has identified a number of potential ideas/topics as outlined throughout this report and will encourage other researchers and collaborators to pursue as appropriate.

Short List of Research Themes and Projects to Address Future Data needs and Gaps

In support of the objective to “develop a short list of research themes/projects to address future data needs and gaps,” several presentations were provided and discussed. The presentations discussed potential project or research themes that could be considered as a future need and address knowledge gaps:

- Impacts of changing energy dynamics of marine phase Atlantic salmon and their prey (Tim Sheehan, NOAA)
  - Brief overview: Historical, contemporary, and future samples (e.g., stomach samples, scale samples, various tissue samples) will be analyzed by various methods (e.g., diet analysis, growth extraction, compound-specific stable isotope

analysis, standard stable isotope analysis, region of origin analysis) to provide an overview of the energy assimilation of fish sampled at West Greenland to investigate if changes in these dynamics, as related to large scale climate forcing in the Northwest Atlantic, are negatively impacting survival and productivity.

- Greenland telemetry (acoustic and PSAT/ROAM) and the Atlantic Salmon Telemetry Planning Meeting: Expanding the tracking network into the North Atlantic (Jon Carr, Atlantic Salmon Federation)
  - Brief overview: Describe the spatial and temporal marine distribution of Atlantic salmon captured and released at West Greenland via numerous electronic tagging methods.
- Lost at Sea – Identifying migration patterns and marine foraging areas of North American Atlantic salmon populations (Brian Hayden, University of New Brunswick)
  - Brief overview: Describe the marine migration of Atlantic salmon sampled at various marine stages via stable isotope based reconstructions of marine forage areas.

The ensuing discussions are summarized below by topic.

Impacts of changing energy dynamics of marine phase Atlantic salmon and their prey

- The energy dynamics proposal outlined within the presentation was only focused on the 2-sea-winter (2SW) component and may not inform first year energy dynamics. However, changes in growth, condition, and productivity of this life history type may be influenced by changes in marine energy dynamics throughout the marine stage, and therefore, insights may be gained on the entire marine migration via samples collected at Greenland. There was general support for the proposed project.
- The proposal offered significant value by analyzing a time series of samples at minimal cost. The methods outlined were appropriate given the questions being asked.
- Analysis of European-origin salmon sampled at Greenland would enhance the output and provide comparison between the 2 stock complexes.
- Interpreting the energy assimilation in time and space needs careful consideration (i.e. is an energy density measured from a sample a reflection of energy consumed just prior to sampling or over the past few days, weeks, or months?) Estimating energy density from a variety of tissue types (scales, liver, muscle, etc.) that have different assimilation rates may help inform the assimilation question. Also, focusing sample collection at the end of the fishing season at Greenland may help provide energy density estimates derived from feeding at West Greenland, specifically (i.e., a “Greenlandic” signature).

Greenland telemetry (acoustic and PSAT/ROAM) and the Atlantic Salmon Telemetry Planning Meeting: Expanding the tracking network into the North Atlantic

- The Greenland tracking program focuses only on the 2SW component and will not provide information about first year dynamics. However, if the proposed ROAM tags can be sufficiently reduced in size, they may eventually be appropriate for use on postsmolts caught in the ocean (e.g., postsmolts migrating through the Strait of Belle Isle). Also, the proposed ROAM archival tag may be appropriate for use on outmigrating smolts. It was noted that the requirement to recover the archival tag for access to its data will result in only the survivors being studied, which may provide biased insights into the marine dynamics of the species. Despite this caveat, using this method would still be a major advancement in our understanding of the migration and environmental conditions of marine-phase Atlantic salmon migration. There was general support for the proposed project and support for further research and development of ROAM tags.

Lost at Sea – Identifying migration patterns and marine foraging areas of North American Atlantic salmon populations

- The overview was intended to stimulate discussion on stable isotopes as an approach to answer questions related to marine dynamics of Atlantic salmon. The approach will not provide a precise migration map, but it does offer the opportunity to run a large number of samples at relatively low cost to provide coarse scale movements.
- The stable isoscape of the North Atlantic must be developed further. Some previous work has shown differentiation in stable isotope signatures across time and space (Dempson et al. 2010; Dixon et al. 2012)
- There was general support for this approach, but concerns were raised that it might not significantly advance our understanding of marine migration dynamics, given its lack of specificity. Multiple suggestions were provided that could be explored to improve the technique and eventually provide the desired level of specificity.
    - Analyzing scale samples from archival tag recaptures may be informative as release and recapture locations would be known.
    - The Atlantic Zone Monitoring Program (AZMP, Pepin et al. 2005, http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html) may be a good source of samples to further develop the isoscape.
    - Prey sampling at Greenland may also be another good source of samples to further develop the isoscape.
- Consideration should be given to organizing a workshop to outline the current state of knowledge of stable isotopes and the ability to further our understanding on Atlantic salmon marine dynamics. The workshop would help improve our understanding of stable isotopes as a research tool, and a product from the workshop could be a review paper that focused on the ability of stable isotopes to determine location and feeding signatures. A workshop could address the following topics:
    - Current state of knowledge
    - Realistic potential of the approach to answer questions of interest to Atlantic salmon researchers and managers (e.g. migration dynamics, feeding dynamics)
    - Inventory potential sample sources to address isoscape data gaps
- An alternative approach to a workshop could be to:
    - Conduct a desktop study to gather information, summarize current state of knowledge, evaluate potential, etc.
    - Coordinate and conduct a series of conference calls/meetings to develop a plan to fill in data gaps based on the desktop study conclusions and to bolster baselines for isoscape future modeling efforts.

Predation

- Not much is known about predation on Atlantic salmon at sea as it is difficult to study and quantify given the relatively low abundance of salmon in the Atlantic Ocean. However, presently greater than 95% of the salmon leaving the nearshore environment die, and some are likely to be predated on. Information on predation impacts is lacking for both Atlantic and Pacific salmon. Tim Sheehan noted that of the 25 Atlantic salmon fitted with pop-off satellite tags (2010-2012), a minimum of 3 are believed to have been predated. Future satellite tagging at Greenland has the potential to further inform these rates.

Bottom-up versus top down

- Many studies focus on bottom-up processes as they are typically easier to study, but we do not know if Atlantic salmon productivity is driven by bottom up or top down processes or possibly both processes at different times during their marine residency.

Sex ratios

- Sex ratio data collected to date are solely based on macro-examination of the gonads and therefore are based on relatively low sample sizes since the majority of the harvest fish are landed in the gutted state. It is feasible to determine sex via genetic methods, but there may be additional costs.

Recommendations to improve future fishery sampling efforts

A comprehensive overview of the West Greenland Fishery Sampling Program was provided by Tim Sheehan (ANNEX 7). The presentation described the history of the sampling efforts, the spatial and temporal dynamics of the sampling efforts, and some of the unique considerations associated with the program. Several discussions occurred in response to the presentation and are summarized by topic below:

Need for the Sampling Program

- ICES assessments require biological characteristics of the harvested fish to estimate the number of fish harvested, sea ages to assign harvested fish to cohorts, and COO to assign harvest to stock complex. The 1SW non-maturing stock complex is a significant driver of productivity for many populations. Although most countries have data collection requirements for their fisheries, it was noted that Greenland does not contribute a significant amount to the sampling program relative to what the other participating jurisdictions contribute. Concern was raised that if the sampling program was not conducted by the participating countries, no sampling would occur.
- The sampling program also provides an excellent opportunity to gain relatively inexpensive access to marine phase Atlantic salmon that we would not otherwise have, for continued biological sampling. The West Greenland Sampling Program provides an extremely valuable long-term data series that is essential to unravelling ecological questions about the marine dynamics of Atlantic salmon.
- It is important to continue to explain to all interested stakeholders what the program is for, why it is needed, and what the impacts are if it is not conducted.

Potential additions

- Genetic analysis to determine sex of all sampled individuals.
- Establish an independent monitoring program with a few select fishers setting gear annually in predetermined locations and tending gear in a standardized manner. The samplers could interact with the fishers by verifying catch records and sampling the harvested fresh whole fish.
- Consider implementing a separate enhanced sampling program (i.e., SALSEA Greenland II) to evaluate the temporally stability of the findings from the original SALSEA Greenland effort.
- Consider working with individual fishers to organize standardized offshore surveys.
- Conduct biological sampling at East Greenland.

Overall assessment

- It is critical that the West Greenland Sampling Program continue, as this program represents the only opportunity to access both North American and European origin fish at this critical life stage.
- The logistics of the program are well organized and implemented and meet all objectives for ICES and NASCO for the provision of catch advice. The transfer of information between samplers within season and between years has proved very useful. The sampling diaries are an ideal tool and provide an archive of sampling logistics and community details for future samplers.
- Further investment in the existing sampling program would be more cost effective than initiating new research endeavors investigating the marine dynamics of Atlantic salmon, especially the 2SW component of North American and Southern European stocks.
- The current program could be expanded if there were requests for specific samples or procedures (e.g., tagging studies). Each request must be evaluated carefully to avoid increasing the cost and or logistical burden.
- There is a desire to increase European participation in the program beyond sampler participation. Currently, the only other commitment of European participation is to act as a clearing house for coded wire tags recovered (UK [England & Wales]). Opportunities exist to increase European participation via sample processing, data analysis, or additional sampling. These additions may help to increase support and funding for European participation in the program. Efforts should continually be made to communicate the results of the sampling program and actively include European sampling partners in analyses, reports, and publications being generated, which use data originating from the sampling program.
- The West Greenland Sampling Program is organized under the auspices of an agreement between the members of the West Greenland Commission of NASCO made during their annual meeting (NASCO 2017 [see WGC(17)8]). The agreement outlines the roles and responsibilities of each party to the program. As an example, the European Union agreed to provide a minimum of 8 person-weeks to sample Atlantic salmon at West Greenland during the 2017 fishing season; the United States agreed to coordinate the sampling program for 2017. It was noted that the Government of Greenland has a number of commitments outlined within the sampling agreement that are often not implemented fully. The Government of Greenland, in cooperation with the Greenland Institute of Natural Resources, agreed to provide support for the sampling program and agreed to sample

Atlantic salmon from the city of Nuuk on a weekly basis starting in 2015 (NASCO 2015 [see WGC(15)21], NASCO 2016 [see WGC(16)9], NASCO 2017 [see WGC(17)8]). These annual commitments have not been met. Engagement by the Government of Greenland is essential and would benefit the sampling program immensely by providing consistent and standardize sampling within the city of Nuuk at very low cost.

Develop Protocols for Access to Databases and Archived Samples for Collaborating Researchers.

The West Greenland Sampling database is a valuable asset containing data on biological characteristics of salmon captured at West Greenland from 1968 to the present, is derived from a large, multinational, annual sampling program, and contains critical information that continues to inform numerous Atlantic salmon management and science efforts.

Controlling access to sampling databases and associated samples is a common problem for agencies/groups who conduct monitoring programs. Access to data is typically straightforward as it often relies on simple data requests and data queries with outputs provided back to the requester. However, it is important that the requester clearly outlines the goals and objectives of the project and how the requested data will support the project so that database owners and managers may evaluate the appropriateness of the request. Access to archived samples is a more problematic issue than are data requests. Archive samples offer a wealth of information relating to sampled individuals and past conditions. However, the processing of these samples may sometimes necessitate the destruction of the archive material. In some instances, this destruction may be acceptable given the expected knowledge gain. There may also be sufficient scale or tissue material to support many analyses. However, once the archive material is exhausted, no further analyses can be conducted. If new and improved future techniques are developed that could further unlock critical information from the archived material, the opportunity for future study may be lost without careful and long term planning for the samples.

The group discussed this topic and provided recommendations for database management and storage, data access, and sample access for the near future as summarized below:

- The database will continue to be housed at the DFO Northwest Fisheries Science Center in St John’s Newfoundland, Canada. The current database steward is Martha Robertson.
- A small committee of representatives from recent contributors to the sampling program will serve as the jurisdictional representatives of the database and archived samples. The group should consist of a single representative from each of the following jurisdictions (2 representatives are expected from Ireland since 2 different agencies contribute to the program annually):
    - Canada, USA, Ireland (Marine Institute), Ireland (Inland Fisheries Ireland), UK (England & Wales), UK (Scotland), and UK (Northern Ireland)
- Data and sample requests should be emailed to the database steward. The database steward will review the request and forward it the representatives from the jurisdictions identified above. Email correspondence between committee members will determine the validity of the request and the appropriate actions to be taken.
- This committee should consider developing a research agreement that outlines conditions for access to of data and samples. As an example:

  - All raw data/results will be provided back to the database steward for inclusion into the sampling database. Access to these data/results by noncollaborators will be restricted until a set time period (to be determined) has expired.
- A condition was suggested for any request involving measuring scales to extract growth metrics or any destructive sampling would require that there must already be an archived image of the scale with an appropriate scalar bar or measurement data to support any future growth extraction efforts. If an image does not exist, the requester must provide one using acceptable image software as part of the collaboration.
- The database steward must be notified of any potential request as early as possible, especially prior to a request for proposal funding being submitted. This will allow the database steward to communicate with the committee identified above and to advise the requester prior to proposal submission of the appropriateness of the request and the likelihood of sample access.

Need for a full inventory of archived scale samples

- A detailed inventory of the archive scale samples is needed. Discrepancies between the archived samples and the database have been previously noted in this report. In addition, the quantity and quality of the archived scale samples are not known. In support of an ongoing research project undertaken by NOAA Fisheries Service, the Gulf of Maine Research Institute, and DFO, a partial inventory can be provided for years 1968-1999 and 2013-2015. This partial inventory will fall short of the detailed inventory required. All participants were in full agreement that this detailed inventory is necessary.
- As part of the inventory, the following should be recorded or undertaken:
  - Verification of the existence of samples, the sample details, annual updates to the database.
  - Add to the database an estimated number of scales available in each envelope for each sample (e.g., <10, ~10-20).
  - Each scale envelope should be labelled with a unique bar code. The bar code should also be included in the database.
  - All future scale samples should also receive a unique bar code and be included into the database.
- It was suggested that the ASRJV should consider supporting the completion of a comprehensive inventory of archived West Greenland Sampling Program scale samples.

REFERENCES CITED

Bradbury IR, Hamilton LC, Sheehan T., Chaput G, Robertson MJ, Dempson JB, Reddin D, Morris V, King T, Bernatchez L. 2016. Genetic mixed stock analysis disentangles spatial and temporal variation in composition of the West Greenland Atlantic Salmon fishery. ICES Journal of Marine Science 73:2311-2321.

Dempson JB, Braithwaite VA, Doherty D, Power M. 2010. Stable isotope analysis of marine feeding signatures of Atlantic salmon in the North Atlantic. ICES Journal of Marine Science 67:52–61.

Dixon H, Power M, Dempson JB, Sheehan TF, Chaput G. 2012. Characterizing trophic status and shift in Atlantic salmon, *Salmo salar*, from freshwater to marine life cycle phases. ICES Journal of Marine Science 69(9):1646–1655.

Gilbey, J, Wennevik, V, Bradbury, IR, Fiske, P, Hansen, LP, Jacobsen, JA, Potter, T. 2017. Genetic stock identification of Atlantic salmon caught in the Faroese fishery. Fisheries Research 187:110–119.

Ó Maoiléidigh, N, White, J, Hansen, LP, Jacobsen, JA, Potter, T, Russell, I, Reddin, D, *et al*. 2018. Fifty years of marine tag recoveries from Atlantic salmon. ICES Cooperative Research Report No. 343. 121 pp.

Jeffery NW, Wringe BF, McBride M, Hamilton LC, Stanley RRE, Bernatchez L, Bentzen P, Beiko RG, Clément M, Gilbey J, Sheehan TF, Bradbury I R. 2018. Range-wide regional assignment of Atlantic salmon (*Salmo salar*) using genome wide single-nucleotide polymorphisms. Fisheries Research 206: 163-175

Mills KE, Pershing A, Sheehan TF, Mountain D. 2013. Climate and ecosystem linkages explain widespread declines in North American Atlantic salmon populations. Global Change Biology 19:3046-3061.

Minke-Martin V, Dempson BJ, Sheehan TF, Power M. 2015. Otolith-derived estimates of marine temperature use by West Greenland Atlantic salmon (*Salmo salar*). ICES Journal of Marine Science 72(7):2139–2148.

Mork KA, Gilbey J, Hansen LP, Jensen AJ, Jacobsen JA, Holm M, Holst JC, Ó Maoiléidigh, N., Vikebø F, McGinnity P, Melle W, Thomas K, Verspoor E, Wennevik V. 2012. Modelling the migration of post-smolt Atlantic salmon (*Salmo salar*) in the Northeast Atlantic. ICES Journal of Marine Science 69:1616–1624.

NASCO (North Atlantic Salmon Conservation Organization). 2015. Report of the Thirty-Second Annual Meetings of the Commissions. Happy Valley-Goose Bay, Canada, 2–5 June 2015.

NASCO (North Atlantic Salmon Conservation Organization). 2016. Report of the Thirty-Third Annual Meetings of the Commissions. Bad Neuenahr-Ahrweiler, Germany, 7-10 June 2016.

NASCO (North Atlantic Salmon Conservation Organization). 2017. Report of the Thirty-Fourth Annual Meetings of the Commissions. Varberg, Sweden, 6-9 June 2017.

Pepin P, Petrie B, Therriault JC, Narayanan S, Harrisson WG, Frank KT, Chassé J, Colbourne EB, Gilbert D, Gregory D, Harvey M, Maillet GL, Mitchell M, Starr M. 2005. The Atlantic Zone Monitoring Program (AZMP): Review of 1998-2003. Can. Tech. Rep. Hydrogr. Ocean Sci. 242: v + 87 p.

Reddin DG, Short PB. 1991. Postsmolt Atlantic salmon (*Salmo salar*) in the Labrador Sea. Canadian Journal of Fisheries and Aquatic Sciences 48:2–6.

Renkawitz MD, Sheehan TF, Dixon H J, Nygaard R. 2015. Changing trophic structure and energy flow in the Northwest Atlantic: implications for Atlantic salmon feeding at West Greenland. Marine Ecology Progress Series. 538:197–211.

Sheehan TF, Reddin DG, Chaput G, Renkawitz MD. 2012. SALSEA North America: A pelagic ecosystem survey targeting Atlantic salmon in the Northwest Atlantic. ICES Journal of Marine Science. 69(9)1580-1588.

ANNEX 1: WORKSHOP PARTICIPANT LIST

1. Ian Bradbury (Fisheries and Oceans Canada), Ian.Bradbury@dfo-mpo.gc.ca
2. Jon Carr (Atlantic Salmon Federation, Canada), jcarr@asf.ca
3. Gérald Chaput (Fisheries and Oceans Canada), Gerald.Chaput@dfo-mpo.gc.ca
4. Brian Dempson (Fisheries and Oceans Canada), Brian.Dempson@dfo-mpo.gc.ca
5. Trish Edwards (Fisheries and Oceans Canada), Patricia.Edwards@dfo-mpo.gc.ca
6. Dennis Ensing (Agri-food and Biosciences Institute, UK (Northern Ireland)), Dennis.Ensing@afbini.gov.uk
7. Michelle Fitzsimmons (Atlantic Salmon Federation, Canada), mgfitzsimmons@gmail.com
8. Brian Hayden (University of New Brunswick, Canada), brian.hayden@unb.ca
9. Nick Kelly (Fisheries and Oceans Canada) , Nicholas.Kelly@dfo-mpo.gc.ca
10. Michael Millane (Inland Fisheries Ireland, Ireland), Michael.Millane@fisheriesireland.ie
11. Kathy Mills (Gulf of Maine Research Institute, USA), kmills@gmri.org
12. Niall Ó Maoiléidigh (Marine Institute, Ireland), niall.omaoileidigh@marine.ie
13. Sebastián Pardo (Dalhousie University, Canada), sebpardo@gmail.com
14. Martha Robertson (Fisheries and Oceans Canada), Martha.Robertson@dfo-mpo.gc.ca
15. Ian Russell (Centre for Environment, Fisheries and Aquaculture Science, UK (England and Wales)), ian.russell@cefas.co.uk
16. Timothy Sheehan, Chair (NOAA Fisheries Service, USA), Tim.Sheehan@noaa.gov
17. Simon Thorrold (Woods Hole Oceanographic Institute, USA), sthorrold@whoi.edu
18. Marc Trudel (Fisheries and Oceans Canada), Marc.Trudel@dfo-mpo.gc.ca

ANNEX 2: WORKSHOP AGENDA

Thursday December 7, 2017

Time	Topic	Lead(s)
10:00	- Introductions, etc. - ASRJV overview - Workshop overview	- All - Trish Edwards - Tim Sheehan
10:30	- Review historical/current state of knowledge of Atlantic salmon at West Greenland - Discussion	- Tim Sheehan (WP #1) - All
11:30	- Review current research efforts on Atlantic salmon at West Greenland - Discussion	- Tim Sheehan (WP #2) - All
12:00	Lunch (provided)	
13:00	- Review inventory of archived databases - Discussion	- Michelle Fitzsimmons (WP #3) - Niall O'Maoileidigh (ICES CRR #282) - All
14:30	BREAK (refreshments provided)	
15:00	- Review inventory of archived samples - Discussion	- Michelle Fitzsimmons (WP #3) and Tim Sheehan (WP #4) - All
16:00	- Compile future data needs and gaps	- All
17:00	Adjourn for the day	

Friday December 8, 2017

Time	Topic	Lead(s)
8:30	Coffee provided	
9:00	- Review previous day	- All
9:30	- Compile future data needs and gaps (cont'd)	- All
10:30	BREAK (refreshments provided)	
11:00	- Compile future data needs and gaps (cont'd)	- All
12:00	Lunch (provided)	
13:00	- Develop research themes/projects to address data needs/gaps *Examples:*	- All

	- *Impacts of changing energy dynamics of marine phase Atlantic salmon and their prey* - *Greenland telemetry (acoustic and PSAT/ROAM)* - *Atlantic Salmon Telemetry Planning Meeting: Expanding the tracking network into the North Atlantic* - *Lost at Sea – Identifying migration patterns and marine foraging areas of North American Atlantic salmon populations*	- Tim Sheehan - Tim Sheehan - Jon Carr - Brian Hayden
14:30	**BREAK (refreshments provided)**	
15:00	- Develop research themes/projects to address data needs/gaps (cont'd)	- All
17:00	**Adjourn for the day**	

Saturday December 9, 2017

Time	**Topic**	**Lead(s)**
8:30	**Coffee provided**	-
9:00	- Review previous day	- All
9:30	- Overview of current sampling program - Improving future fishery sampling	- Tim Sheehan (WP #5) - All
10:30	**BREAK (refreshments provided)**	
	- Improving future fishery sampling (cont'd)	- All
12:00	**Lunch (provided)**	
13:00	- Database/ samples access protocols	- All
14:30	**BREAK (refreshments provided)**	
15:00	- Database/ samples access protocols (cont'd)	- All
16:30	- Next steps: o Workshop Report back to ASRJV o Presentation to ICES WGNAS/NASCO o What else?	- Tim Sheehan
17:00	**Adjourn for the day (*if not earlier*)**	

ANNEX 3: Review of historical/current state of knowledge of Atlantic salmon at the summer feeding area off the coast of West Greenland

Not to be cited without permission of the authors

Atlantic Salmon Research Joint Venture Workshop: Current status of knowledge, data, and research efforts on Atlantic salmon at Greenland: what do we have, what do we need, and what should we do moving forward?

Project Number: GULF2016.21

Working Paper 2018/1

Review of historical/current state of knowledge of Atlantic salmon at the summer feeding area off the coast of West Greenland

Mark Renkawitz[1] and Timothy F. Sheehan[2]

[1]NOAA Fisheries Service

Northeast Fisheries Science Center

166 Water Street

Woods Hole, MA 02540 USA

(508) 495-2212

Mark.Renkawitz@noaa.gov

[2]NOAA Fisheries Service

Northeast Fisheries Science Center

166 Water Street

Woods Hole, MA 02540 USA

(508) 495-2215

Tim.Sheehan@noaa.gov

Table of Contents

Introduction

Changes in large-scale climate conditions in the Northwest Atlantic are hypothesized to have caused a phase shift in productivity, which altered trophic pathways that influence the growth, survival, productivity, and abundance of many species. Concurrent abundance declines of disparate North America and European Atlantic salmon populations despite diverse population structures and management regimes suggests that conditions experienced at common marine areas (i.e., West Greenland) may be causative. This document summarizes the published research on various topics related to Atlantic salmon research conducted at West Greenland with special focus on activities associated with the International Sampling Program (conducted since 1968). In addition to providing an outline of the current state of knowledge of Atlantic salmon at Greenland, this document may be useful in helping inform future research needs and help fine-tune the efficacy of future sampling efforts.

The Atlantic Salmon Fishery at West Greenland

Atlantic salmon were reported from the coastal waters of West Greenland as early as 1935, from bycatch in groundfish gear (Jensen 1939). Directed exploitation of salmon is thought to have begun around 1959 when local fishers set fixed gillnets within fjords and along the coast (Parrish and Horsted 1980). By the mid-1960s, a summer/autumn fishery was persecuted exclusively by Greenlandic fishers along the west coast of Greenland. In 1965, Faroese and Norwegian fishers introduced offshore fishing (usually within 40 nautical miles of the coast) with drift gillnets and the fishery expanded rapidly. The reported harvest reached ∼1300 mt by the late 1960s, eventually peaking at ∼2700 mt in 1971 (ICES 2017). Following this peak, landings declined due to a combined effect of decreasing abundance and increased fishery management measures.

Starting in 1998, landings were restricted to an amount for internal consumption only (no export), which was estimated to be approximately 20 mt. Reported landings from 1998-2000 averaged 17 mt. In 2001, a commercial fishery was once again allowed with an *ad hoc* management program the allowable catch to be determined based on in-season CPUE calculations. Final reported landings were 43 mt. This scheme was adopted in 2002, although the commercial quota was bought prior to the fishery and reported landings were 9 mt. For the period 2003-2014, the quota was set to nil and the fishery was restricted to catches used for internal consumption only with average reported landings of approximately 30 mt. For the period 2015-2017 an annual quota of 45 mt for all sectors of the fishery was unilaterally set by the Government of Greenland. The fishery remained restricted to catches used for internal consumption, although factory landings were allowed in some years. Reported landings for 2015-2016 were 57 mt and 27 mt respectively. Since 2000, unreported catch has been estimated at 10 mt annually.

Sampling Program Dynamics

The sampling program at West Greenland has consisted of three primary phases: 1) research surveys (1969-1976, 1978-1980, and 1982), 2) factory landings sampling (1978-1992, 1995-1997, and 2001), and 3) the contemporary commercial landings (i.e. markets, businesses and processing plants) sampling program (1998-2000 and 2002-2017). During the first phase, research surveys were conducted by Fisheries and Oceans Canada and other countries participated sporadically. Compendium papers were produced in an ICES/ICNAF publication, and serve as the basis for many contemporary research efforts (Parrish and Horsted 1980, see also Templeman 1967, May 1973, Reddin 1988). Surveys were conducted by deploying gillnets along the West Greenland coast and offshore banks to obtain representative samples from the West Greenland stock complex. Biological characteristics data including scale samples were collected along with other requested samples and oceanographic data to support related research efforts (Templeman 1967, Parrish and Horsted 1980).

Factory landings sampling began in 1978 and overlapped with the research surveys in four years. Sampling teams were assigned to individual factories and therefore there is a potential bias in sampling results as not all factories or regions receiving salmon were sampled and sampling was not conducted throughout the entire fishing season. Further, sampling was often conducted on fish that were pre-sorted by size and therefore caution is advised when utilizing data a collected.

The contemporary sampling program has been conducted since 1998 (with the exception of 2001) and is primarily conducted in open air markets in communities along the coast. Baseline sampling (biological characteristics, scale samples and tissues samples) is collected on an annual basis, but some ‘enhanced’ sampling effort is conducted at the request of NASCO or collaborators (e.g. SALSEA West Greenland, 2009-2011). Biological samples are collected throughout the fishery from August-October or until the fishery is closed once the quota is obtained. Effort is made to maximize the spatial and temporal coverage of the fishery by placing samplers along the coast and throughout the fishing season to obtain representative sampling from the fishery (Sheehan et al. 2013, Sheehan et al. 2015a, Sheehan et al. 2015b, Sheehan et al. 2017, ICES 2017).

Biological characteristics and demographics

Biological characteristics, age (obtained from scales), and continent or region of origin statistics (obtain from scales and/or genetic analysis from tissue samples) have been reported annually by the ICES Working Group on North Atlantic Salmon (WGNAS). From 1969 to 2015 the uncorrected mean weight of Atlantic salmon sampled at West Greenland declined from high values in the 1970s to the lows from 1990 to 1995, and thereafter increased (ICES 2017). Additionally, while the length of sampled European fish appeared to decrease from 1960-2010, the length of fish from North American origin increased. However, these trends are partially an artifact of factors associated with spatiotemporal differences in sampling over the time series (ICES 2015) and highlight the need to incorporate space and time in any analysis using these biological characteristics data. With the evolution of the sampling program over time, there has been a shift in the temporal coverage of the sampling which could impart significant biases in the data collected. Sampling in the early part of the time series was abbreviated an occurred earlier in the fishing season compared to the later part of the time series. Trends in whole weight during research survey sampling are negative over time, while no trends in whole weight were evident during the factory sampling period. Whole weights for both North American and European origin fish have declined since the early 2000's. In term of growth over the three month fishing season, salmon can increase in weight by approximately 1 kg (approximately 30-40%), which further highlights the importance of considering temporal components of the three sampling periods when analyzing biometric data.

Continent, Country and Region of Origin

A variety of methods and techniques have been utilized to determine the continent, country, and region of origin of the Atlantic salmon harvested at West Greenland. Historically, scale pattern analysis allowed for determination of continent of origin and suggested that 34-75% of the West Greenland harvest was North American origin from 1969-1997 (Reddin and Friedland 1999). Cross-validated misclassification error rates ranged from 0.0-25.7% for North American fish and 0.0-12.0% for European fish. Additionally, data suggest that North American salmon were more commonly recovered at northern latitudes and further inshore when compared to fish from European origins which were more often caught at southern clines and along offshore banks. Tag return data collected from 1961 to the present has shown a similar trend (Reddin et al. 2012). It was suggested the variability in the timing of smolt emigration, differences in ocean currents experienced, or various other oceanographic conditions encountered during the first year at sea play a substantial role in the physical structuring of stock complexes along the coast (Reddin et al. 2012). Otolith morphology has also been used to determine continent and country of origin of known origin (i.e. Carlin tagged) fish from West Greenland from 1986-1988 (Friedland and Reddin 1994). Classification efficiency at the continent of origin between North America and Europe was 88%. Classification efficiency between USA and Canada was 64% while classification accuracy between Ireland and Scotland was 69%.

Since 2002, continent of origin estimates have been generated via likelihood-based assignments of multi-locus microsatellite genotypes with 100% accuracy (King et al. 2001). Sheehan et al. (2009) used these genetic data and estimated misclassification rates, a probabilistic-based genetic assignment model (PGA) was developed to estimate the contribution of Canadian and individual USA rivers to the West Greenland salmon harvest from 2000-2003. Gauthier-Ouellet et al. (2009) analyzed 2835 Atlantic salmon collected During the West Greenland fishery from 1995-2006 using 13 microsatellites and a baseline of 52 individual North American populations from 9 distinct regions to estimate region of origin of the harvest and found that the harvest of regional groups was proportional to their productivity. Using a genetic mixture analysis and individual assignments and an improved North American baseline, Bradbury et al. (2015) determined that the majority of the North American contributions were from Labrador, Southern Gulf/Gaspe Breton, and the Gaspe Peninsula regions (78%). Additionally, by comparing the pre-1990 and post-1990 assignments, there is evidence of a shifting contribution with the more southerly North American populations contributing more to the Greenland harvest prior to 1990. It should be noted that the sample sizes prior to 1990 were low and further work is recommended (Bradbury et. al 2015).

An attempt was made to utilize parasites as biotags to partition the continent of origin of the salmon harvest at West Greenland. However, heterogeneity of *Eubothrium crissum* and *Anisakis simplex* within the stocks precluded this (Pippy 1980).

The Kapisillit River is located in the upper Nuup Kangerlua fjord near Nuuk, and is believed to house the only self-sustaining Atlantic salmon population in Greenland (Hansen 1965). One small scale study conducted by Knox et al. (2002) used polemerase chain reaction (PCR) reaction of amplified mitochondrial DNA to show that Kapisillit River Atlantic salmon is fixed for a haplotype present in both Baltic and European populations.

Migration Dynamics and Distribution

Tag recoveries in Atlantic salmon at Greenland revealed that this mixed-stock included fish from the USA, Canada, Greenland, Iceland, the Faroes, Spain France, Ireland, Wales, England Scotland and Norway (Reddin et al. 2012). Studies in the US and Canada with subsequent recaptures along the West Greenland coast, and studies in Greenland with subsequent recaptures in home waters generated the first insights into the migration dynamics of salmon at sea. Straight line swimming speeds of recaptured North American and European Atlantic salmon did not change from 1960-2010.

The northern limit of Atlantic salmon at Greenland is assumed to be governed by temperature (4 °C) and around the Disko Bay region (Reddin 1988). Individual stocks of Atlantic salmon do not appear to be randomly distributed along the coast of West Greenland, but the patterns of occurrence appear to vary annually possibly due to annual variation in the environmental conditions in the Northwest Atlantic (Reddin and Shearer 1987). Fish from North America tend to increase in proportion with latitude compared to fish from European origin (Reddin et al. 2012). However, the distribution of salmon populations from North American populations has been found to be fairly homogeneous along the West Greenland coast (Gauthier-Ouellet et al. 2009, Bradbury et al. 2015) since the mid-1990’s.

More recent examination of the migration dynamics of salmon tagged at Greenland suggest the timing of migration away from the coast after the feeding season is not uniform, as some fish move into the Labrador Sea during early autumn while some can remain along the shelf into the winter before moving into the ocean (Renkawitz et al. *in review*). Additionally a larger area of the Labrador Sea than previously hypothesized may provide Atlantic salmon with overwintering habitat before the spring spawning migration.

Aquaculture Escapement

The incidence of aquaculture escapees at West Greenland is low, between 1.1-1.4% (Hansen et al. 1997). Considering the large number of annual escapees, their absence could stem from low production of farmed salmon in North America compared to Europe (primarily Norway and Scotland). Additionally, the timing of escapement may not align with natural maturity schedules and therefore escaped salmon may not follow wild salmon migratory pathways to marine feeding areas. The identification of aquaculture escapees has been very low and is still considered insignificant.

Thermal Habitat

Otolith microchemistry has been used to estimate thermal habitat use of Atlantic salmon at sea. Fishery samples from the SALSEA West Greenland effort in 2009 and 2010 were analyzed from three communities along the West Greenland coast (Minke-Martin et al. 2015). Of 40 one sea-winter (1SW) North American origin salmon analyzed with oxygen isotope stable isotope spectrometry, thermal habitat estimates ranged from 3.9 to 9.7 °C. However, estimated temperatures did not correlate with estimates of growth obtained from the otoliths and it was hypothesized that the discrepancy is the result of the interaction between temperature and food ration of patchy prey resources. Temperatures experienced by 1SW salmon tagged with pop-up satellite tags during autumn in West Greenland ranged from -0.6 °C to 8.4 °C during the second winter in the Labrador Sea with 80-89% of the measurements between 4°C and 7°C (Renkawitz et al. *in review*). It was suggested that when salmon reach ambient conditions below 0 °C, there is a direct and rapid movement into warmer water possibly to avoid contact with sea ice. The results of these independent studies are consistent with survey catches from 1965-1991, which suggest peak abundance of salmon in the Labrador Sea occurs between 7.0-8.5 °C, and that 80% of salmon can be found between 4-10 °C (100% catch range = 3.0-13.0 °C; Reddin and Friedland 1993). Reddin and Friedland (1993) suggest that 4 to 10 °C is the primary thermal habitat for foraging immature adult salmon in the Northwest Atlantic and that fish may actively seek these conditions as a result.

Swimming Depth

Atlantic salmon fitted with pop-up satellite tags (2009-2011) primarily (approximately 87%) occupy the top 10 meters of the water column while over the West Greenland shelf, but dives up to 250 m were recorded (Renkawitz et al. *in review*). This surface orientation is maintained in the Labrador Sea proper and diving activity up to 750 meters has been recorded.

Feeding

Stable isotope analysis of tissue samples collected during SALSEA West Greenland from 2009-2011 demonstrated that marine phase salmon rely heavily on pelagic food webs and appear to be opportunistic generalists while some individuals appear to exhibit specialist tendencies (Dixon et al. 2017). Atlantic salmon from North American and European stocks consume the same prey items when they overlap in space and time off the coast of West Greenland (Renkawitz et al. 2015) and stomach content composition and weight did not differ between sexes or sea ages.

Atlantic salmon consume a broad range of fish and invertebrates (i.e. Atlantic herring, capelin, Atlantic cod, Greenland cod, Arctic cod, pollock), sculpin (Cottoidei), krill (Euphausiidae) and various taxa of amphipods (i.e., Hyperiidae, Gammariidae, etc.). A broad size spectrum of prey can also be consumed, ranging from at least 2-21 cm (Renkawitz et al. 2015). From the mid-1960’s to the mid-1970's, the main prey items along the West Greenland coast were capelin, amphipods (likely Themisto sp.), and to a lesser degree sandlance and euphausiids, although there was variability among NAFO areas (Hensen 1965, Templeman 1967, Lear 1972, Lear 1980). The contemporary diets of Atlantic salmon at Greenland (Renkawitz et al 2015) were similar to the historic diets and were dominated by capelin (40-90% annually) and Themisto sp. although the latter was highly variable (1-54%). Standardized stomach content weight and proportions of taxa consumed were similar among historic (1965-1970) and contemporary (2006-2011) samples although there were some notable difference. There was a 12% reduction in biomass consumed, a 21% reduction in capelin consumed, and a 15% increase in Themisto consumed in the recent years. In addition, the boreoatlantic armhook squid, which was absent from historic inshore diet records, appear to be an important contemporary diet item (up to 16%), particularly in the north. Furthermore, from 1968-2008 mean energy density estimates of the keystone forage species, capelin, decreased by approximately 37.5%, resulting in 20-58% reduction in total energy consumption. These results suggest that altered trophic dynamics caused by 40 years of changing ocean conditions may be negatively influencing the productivity of Atlantic salmon as well as a variety of other species in the Northwest Atlantic (Renkawitz et al. 2015).

Maturity

Templeman (1966) reported that the sex ratio of salmon in 1966 in West Greenland 5:7 (males:females). All males and females were immature. Males had thin gonads ranging from 4-8mm, and the few females that had begun ovary development had egg diameters ranging from 0.40-0.99 mm. Using egg protein precursor values (i.e., plasma vitellogenin (Vg) values) it was determined that of 45 female salmon sampled in West Greenland from August to November 1974-1978, 43 would not be spawning that year. Two females had high Vg values and were assumed to be returning to the Kapisillit River to spawn (Ideler et al. 1981).

As part of the SALSEA West Greenland sampling program, sex identified by gonadal examination was conducted on approximately 1200 individuals. The overall sex ratio was 14% males (n=167) to 86% females (n=1041). Ovary samples were collected in 2010 for development analysis, but the results are not available.

Parasites

In historic sampling efforts, seventeen different parasites have been detected in various tissues of Atlantic salmon sampled at West Greenland, some of freshwater origin and some of marine origin (Pippy 1980). Parasites were found on the eyes, gills, liver, spleen, among the visceral tissue generally and specifically in the stomach, intestines, pyloric caecae. The salmon louse, *Lepeophtheirus salmonis*, is an external copepod that was found on most salmon examined from July-August in 1965. Most specimens were females with egg sacks (Templeman 1966). The tapeworm, *Eubothrium crassum*, was found in 27% of the salmon sampled and they filled most of the pyloric caecae and appeared to be spreading into the intestines (Templeman 1966). The incidence and severity of parasitic infestation by tape worms appeared to increase with age (Pippy 1980). An average of 1.2 (range 0-6) larval nematodes (*Anisakis* sp.) were detected on the liver 54% of the salmon examined (Templeman 1966). The gills and gall bladders were examined were examined for *Salmincola salmonea* (i.e. gill louse) and other miscellaneous parasites, but none were detected (Templeman 1966). Only two different parasites (*Diplostomulum* sp. and *Capillaria salvelini*) were found in specimens collected from salmon thought to be from the Kapisilit River, West Greenland (Pippy 1980).

Contemporary sampling during SALSEA West Greenland sampling included collection of the heart, liver intestine, vent, and other visceral tissue for parasite analysis. While some of the samples have been processed, the data have yet to be formally presented. Sea lice infestation was also noted and 70% of the fish sampled had between 1 to over 11 louse on the body (ICES 2013). The actual infestation was likely higher as lice often become dislodged while being retrieved from gillnets, dislodged as they perish before sampling commences, or dislodged as fishers may clean the fish before bringing them to the market where they are sampled. The practice of cleaning the fish of external parasites before returning to market fish appears to be fisher and/or region-specific.

Disease

In 1284 samples collected during the West Greenland fishery from 2003-2011, one salmon tested positive for infectious salmon anemia virus (ISAv; ICES 2015). In 2010 none of the 358 fish sampled during the fishery tested positive for infectious pancreatic necrosis (IPNv; ICES 2015).

Contaminants

Carlsson et al. (2014a,b) published findings associated with contaminant levels of polychlorinated biphenyls, polybrominated diphenyl ethers, and perfluorinated alkylated substances in salmon filets in the context of human consumption. Contaminant levels in the sampled fish were low.

Predators

Little information on predation in West Greenland exists in the primary literature. Porbeagle and Greenland sharks may be occasional predators of Atlantic salmon in West Greenland waters (Templeman 1967; MacNeil et al. 2012). Renkawitz et al. (*in review*) reported that of the 25 Atlantic salmon fitted with popoff satellite tags and released at West Greenland, two appear to have been depredated on by Greenland sharks and one by an Atlantic Halibut. Other predators of Atlantic salmon at West Greenland may include harp and hood seals, orca and minke whales (Sergeant 1963) and other large pelagic fish such as Atlantic bluefin tuna (Lacroix 2012).

References

Bradbury, IR, Hamilton, LC, Sheehan, TF, Chaput, G, Robertson, MJ, Dempson, JB, Reddin, D, Morris, V, King, T, Bernatchez, L. 2015. Genetic mixed-stock analysis disentangles spatial and temporal variation in composition of the West Greenland Atlantic Salmon fishery. ICES Journal of Marine Science. 73: 2311–2321.

Carlson, P, Herzke, D., and Kallenborn, R. 2014a. Enantiomer-selective and quantitative trace analysis of selected persistent organic pollutants (POP) in traditional food from western Greenland. Journal of Toxicology and Environmental Health. 77: 616-627.

Carlson, P, Herzke, D., and Kallenborn, R. 2014b. Polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and perfluorinated alkylated substances (PFASs) in traditional seafood items from western Greenland. Environmental Science and Pollution Research Institute. 21: 4741-4750.

Dixon, HJ, Dempson, JB, Sheehan, TF, Renkawitz, MD, Power, M. 2017. Assessing the diet of North American Atlantic salmon (*Salmo salar* L.) off the West Greenland coast using gut content and stable isotope analyses. Fisheries Oceanography. 26: 555-568.

Dixon, HJ, Power, M, Dempson, JB, Sheehan, TF, and Chaput, G. 2012. Characterizing the trophic position shift in Atlantic salmon (Salmo salar) from freshwater to marine life-cycle phases using stable isotopes. ICES Journal of Marine Science. 69: 1646–1655.

Friedland, KD, and Reddin, DG. 1994. Use of otolith morphology in stock discrimination of Atlantic salmon (Salmo salar). Canadian Joutnal of Fisheries and Aquatic Sciences. 54: 91-98.

Gauthier-Ouellet, M, Dionne, M, Caron, F, King, TL, and Bernatchez, L. 2009. Spatiotemporal dynamics of the Atlantic salmon (Salmo salar) Greenland fishery inferred from mixed-stock analysis. Canadian Journal of Fisheries and Aquatic Sciences. 66: 2040-2051.

Hansen, LP, Reddin, DG, and Lund, RA. 1997. The incidence of reared Atlantic salmon (Salmo salar L.) of fish farm origin at West Greenland. – ICES Journal of Marine Science, 54: 152–155.

Hansen, PM. 1965. Report of recaptures in Greenland waters of salmon tagged in rivers in America and Europe. ICNAF Redbook 1965: Part II 194-201.

ICES. 2017. Report of the Working Group on North Atlantic Salmon (WGNAS), 29 March – 7 April, Copenhagen, Denmark. ICES CM 2017/ACOM:20. 294 pp.

ICES. 2015. Report of the Working Group on North Atlantic Salmon (WGNAS), 17–26 March, Moncton, Canada. ICES CM 2015/ACOM:09. 332 pp.

ICES 2013. Report of the Working Group on North Atlantic Salmon (WGNAS), 3-12 April, Copenhagen, Denmark. ICES CM 2013/ACOM:09. 332 pp.

ICES. 2012. Report of the Working Group on North Atlantic Salmon (WGNAS), 26 March-4 April 2012, Copenhagen, Denmark. ICES CM 2012/ACOM:09. p 320.

Idler, DR., Hwang, SJ, and Crim, LW. 1981. Determination of sexual maturation stages of Atlantic salmon (*Salmo salar*) captured at sea. Canadian Jorunal of Fisheries and Aquatic Sciences. 38:405-413.

Jensen, AS. 1939. Concerning a change of climate during recent decades in the Arctic and subarctic regions, from Greenland in the west to Eurasia in the east, and contemporary biological and geophysical changes. Kgl. Danske Videnskabernes Selskab. Biologiske Meddelelser. 14: 1-75.

King, TL, Kalinowski, ST, Schill, WB, Spidle, AP, and Lubinski, BA. 2001. Population structure of Atlantic salmon (*Salmo salar* L.): a range-wide perspective from microsatellite DNA variation. Mol Ecol 10: 807-821.

Knox, D, Lehmann, K, Reddin, DG, Verspoor, E. 2002. Genotyping of archival Atlantic salmon scales from northern Quebec and West Greenland using novel PCR primers for degraded mtDNA. Journal of Fish Biology. 60:266-270.

Lear, WH. 1980. Food of Atlantic salmon in the West Greenland-Labrador Sea area. ICES Rapport Process-Verbeaux Reunion. 176: 55-59.

Lear, WH. 1972. Food and feeding of Atlantic salmon in coastal areas and over oceanic depths. Research Bulletin International Commission for the Northwest Atlantic Fisheries, 9, 27–39.

Minke-Martin, V, Dempson, JB, Sheehan, TF, & Power, M. 2015. Otolith-derived estimates of marine temperature use by West Greenland Atlantic salmon (*Salmo salar*). ICES Journal of Marine Science. 72, 2139–2148.

Parrish, BB, and Horsted, AA. 1980. ICES/ICNAF Joint Investigation on North Atlantic Salmon. ICES Rapports et Proces-Verbaux des Reunions. 176: 1-148.

Pippy, J.H.C. 1980. The value of parasites as biological tags in Atlantic salmon at West Greenland. ICES Rapports et Proces-Verbaux des Reunions. 176: 76-81.

Reddin, DG, Hansen, LP, Bakkestuen, V, Russell, I, White, J, Potter, ECE, Dempson, JB, Sheehan, TF, O´ Maoile´idigh, N, Smith, GW, Isaksson, A, Jacobsen, JA, Fowler, M, Mork, KA, and Amiro, P. 2012. Distribution and biological characteristics of Atlantic salmon (*Salmo salar*) at Greenland based on the analysis of historical tag recoveries. ICES Journal of Marine Science. 69: 1589-1597.

Reddin, DG. 2006. Perspectives on the marine ecology of Atlantic salmon (*Salmo salar*) in the Northwest Atlantic. Canadian Science Advisory Secretary Research Document. 2006/018.

Reddin, DG, and Friedland, KD. 1999. A history of identification to continent of origin of Atlantic salmon (*Salmo salar* L.) at west Greenland, 1969-1997. Fisheries Research. 43: 221-235.

Reddin, DG, and Friedland, KD. 1993. Marine environmental factors influencing the movement and survival of Atlantic salmon. In D. Milled (Ed) Salmon in the sea and new enhancement strategies (pp. 79-103). Edinburgh: Fishing News Books.

Reddin, DG. 1988. Ocean life of Atlantic salmon (Salmo salar L.) in the northwest Atlantic. In D. Mills & D. Piggins (Eds.), Atlantic salmon: Planning for the future (pp. 483–511). London: Croom Helm.

Reddin, DG, and Shearer, WM. 1987. Sea-surface temperature and distribution of Atlantic salmon in the Northwest Atlantic Ocean. American Fisheries Society Symposium. 1: 262-275.

Renkawitz, MD, Sheehan, TF, Rikardsen, A, Righton, D, Nygaard, R. *In review*. First insights on the habitat use and migration dynamics of immature adult Atlantic salmon tagged at West Greenland with pop-up satellite archival tags.

Renkawitz, MD, Sheehan, TF, Dixon, HJ, and Nygaard, R. 2015. Atlantic salmon (Salmo salar) feeding ecology and energy acquisition at West Greenland. Marine Ecology Progress Series. 538: 197–211.

Sergeant, DE. 1963. Minke whales, Balaenoptera acutorostrata Lacépède, of the Western North Atlantic. Journal of the Fisheries Research Board of Canada 20: 1489–1504.

Sheehan TF, Assunção MGL, Deschamps D, Laughton B, Ó Cuaig M, Nygaard R, King TL, Robertson MJ, Ó Maoiléidigh N. 2013. The International Sampling Program: Continent of Origin and Biological Characteristics of Atlantic Salmon Collected at West Greenland in 2012. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 13-20; 33 p.

Sheehan, T.F., Belleni, L., Coghlan, B., Deschamps, D., Haas-Castro, R., Mee, D., Thomas, K., Nygaard, R., King, T. L., Robertson, M.J., and Ó Maoiléidigh, N. 2015a. The International Sampling Program: Continent of Origin and Biological Characteristics of Atlantic Salmon Collected at West Greenland in 2014. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 15-23; 33 p.

Sheehan, T.F., Davison, P., Deschamps, D., Drumm, A., Millane, M., Morgan, T., Music, P., Niven, A., Nygaard, R., King, T.L., Robertson, M.J., Ó Maoiléidigh, N. 2017. The international sampling program: Continent of origin and biological characteristics of Atlantic salmon collected at West Greenland in 2015. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 17-13; 27 p.

Sheehan T.F., Deschamps D., Trinko Lake T., McKelvey S., Thomas K., Toms S., Nygaard R., King T.L., Robertson M.J., Ó Maoiléidigh N. 2015b. The International Sampling Program:

Continent of Origin and Biological Characteristics of Atlantic Salmon Collected at West Greenland in 2013. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 15-22; 27 p.

Sheehan, TF, Legault, CM, King, TL, and Spidle, AP. 2010. Probabilistic-based genetic assignment model: assignments to subcontinent of origin of the West Greenland Atlantic salmon harvest. – ICES Journal of Marine Science. 67: 537–550.

Templeman, W. 1967. Atlantic salmon from the Labrador Sea and off West Greenland taken during A.T. Cameron Cruise, July-August 1965. International Commission of the Northwest Atlantic Fisheries Research Bulletin. 4: 4-40.

Templeman, W. 1968. Distribution and characteristics of Atlantic salmon over oceanic depths and on the bank and shelf slope areas off Newfoundland, March-May 1966. International Commission of the Northwest Atlantic Fisheries Research Bulletin. 5: 64-85.

Additional References

Andersen, KP, Horsted, SA, Moller Jensen, J. 1980. Estimation of some important population parameters based on the analysis of recaptures from the salmon tagging experiment at West Greenland in 1972. ICES Rapports et Proces-Verbaux des Reunions. 176: 136-141.

Child, AR. 1980. Identification of stocks of Atlantic salmon (Salmo salar L.) by electrophoretic analysis of serum proteins. ICES Rapports et Proces-Verbaux des Reunions. 176: 65-67.

Christiansen, O, and Lear, WH. 1980. Distribution and abundance of Atlantic salmon at West Greenland. ICES Rapports et Proces-Verbaux des Reunions. 176: 22-35.

Doubleday, WG, and Reddin, DG. An analysis of the implications of alternative mesh size for gillnets and the opening dates for commercial salmon fishing season at West Greenland.Canadian Atlantic Fisheries Scientific Advisory Committee. 81/3.

Dunbar, MJ. 1975. On the West Greenland sea-life area of the Atlantic salmon.

Dunbar, MJ, and Thomson, DH. 1979. West Greenland salmon and climate change. Meddelelser om Gronland. 202: 1-19.

May, AW. 1973. Distribution and migrations of salmon in the northwest Atlantic. International Atlantic Salmon Foundation. Special Publication Series. 4: 373-82.

Miller, AS, Sheehan, TF, Renkawitz, MD, Meister, AL, and Miller, TJ. Revisiting the marine migration of US Atlantic salmon using historical Carlin tag data. – ICES Journal of Marine Science, doi:10.1093/icesjms/fss039.

Miller, AS, Sheehan, TF, Spencer, RC, Renkawitz, MD, Friedland, KD, and Meister, AL. 2012. Description of the historic US Atlantic Salmon (Salmo salar L.) tagging programs and subsequent databases. Northeast Fisheries Science Center Reference Document 12-13.

Munro, WR and Swain, A. Age, weight and length distributions and sex ratio of salmon caught off West Greenland. 1980. ICES/ICNAF Joint Investigation on North Atlantic Salmon. ICES Rapports et Proces-Verbaux des Reunions. 176: 43-54.

Payne, RH. 1980. The use of serum transferrin polymorphism to determine the stock composition of Atlantic salmon in the West Greenland fishery. ICES Rapports et Proces-Verbaux des Reunions. 176: 60-64.

Ruggles, CP, and Ritter, JA. 1980. Review of North American smolt tagging to assess the Atlantic salmon fishery off West Greenland. 176: 82-92.

Saunders, RL, Kerswill, CJ, and Elson, PF. 1964. Journal of the Fisheries Research Board of Canada. 22: 625-629.

Smed, J. 1980. Temperature of the waters off southwest and South Greenland during the ICES/ICNAF salmon tagging experiment in 1972. 176: 18-21.

Swain, A. 1980. Tagging of salmon smolts in European rivers with special reference to recaptures off West Greenland in 1972 and earlier years. 176: 93-113.

ANNEX 4: Review current research efforts on Atlantic salmon at the summer feeding area off the coast of West Greenland

Not to be cited without permission of the authors

Atlantic Salmon Research Joint Venture Workshop: Current status of knowledge, data, and research efforts on Atlantic salmon at Greenland: what do we have, what do we need, and what should we do moving forward?

Project Number: GULF2016.21

Working Paper 2018/02

Review current research efforts on Atlantic salmon at the summer feeding area off the coast of West Greenland

Timothy F. Sheehan

NOAA Fisheries Service

Northeast Fisheries Science Center

166 Water Street

Woods Hole, MA 02540 USA

(508) 495-2215

Tim.Sheehan@noaa.gov

INTRODUCTION

Non-maturing 1SW Atlantic salmon from both North America and Europe congregate off the coast of West Greenland during the summer and fall. Considering this and the concurrent decline of this life history type on both sides of the Atlantic, this summer feeding area is hypothesized to be a critical period in the marine residence that may influence overall stock complex productivity. As such, numerous research efforts have been conducted since the 1960's to better understand the marine ecology of this life stage. This working paper attempts to summarize the known ongoing and impending Atlantic salmon research focused at the summer feeding area off the coast of West Greenland. When combined with the past research inventory, this information will allow for informed discussions to develop research themes/projects that address future data needs and gaps.

INVENTORY OF CURRENT RESEARCH EFFORTS

1.*************************************

Proximate composition of primary mid-trophic prey species at West Greenland

Principle Investigators: Mark Renkawitz (NOAA Fisheries Service) and Timothy Sheehan (NOAA Fisheries Service)

Collaborators: Rasmus Nygaard (Greenland Institute of Natural Resources)

Objectives:

1) collect representative *Mallotus villosus*, Themisto sp., and *Gonatus fabrichii* from West Greenland waters
2) analyse the proximate composition of individuals to generate species-specific dry-weight to energy density regressions

2.*************************************

Lipid content of Atlantic salmon (*Salmo salar* L.) at West Greenland

Principle Investigators: Audrey Dean (University of Waterloo) and Michael Power (University of Waterloo)

Collaborators: Timothy Sheehan (NOAA Fisheries Service) and Mark Renkawitz (NOAA Fisheries Service)

Objectives:

1) Determine lipid content of ~1200 Atlantic salmon from West Greenland (SALSEA Greenland, 2009-2011)
2) Describe relationship between lipid content and diet composition
3) Describe relationship between growth and lipid content
4) Describe how the percentage of lipids covaries along a latitudinal gradient.

3.*************************************

Which mechanisms to better understand the demographic and ecological mechanisms underlying changes in life history traits

Principle Investigators: Maxime Olmos (Agrocampus Ouest) and Etienne Rivot (Agrocampus Ouest)

Collaborators: Etienne Prévost (French National Institute for Agricultural Research), Marie Nevoux (French National Institute for Agricultural Research), Mark Payne (Technical University of Denmark), Félix Massiot-Granier (Gulf of Maine Research Institute), Kathy Mills (Gulf of Maine Research Institute), and Timothy Sheehan (NOAA Fisheries Service)

Objectives:

1) Identify long-term time series of life history traits of Atlantic Salmon (Post-smolt survival and Proportion of 1SW maturing) for all population in North America and Southern Europe via a hierarchical Bayesian life cycle model
2) Determine the demographic and ecological mechanisms underlying changes in life history traits.

4.*************************************

Effects of climate-driven ecosystem change on Atlantic salmon growth and survival at sea: analyses of West Greenland salmon

Principle Investigators: Kathy Mills (Gulf of Maine Research Institute), and Timothy Sheehan (NOAA Fisheries Service)

Collaborators: tbd

Objectives:

1) Extract representative sub-sample of growth data from North American origin Atlantic salmon sampled at West Greenland (1969-2016)
2) Determine if growth characteristics of North American Atlantic salmon changed over time.
3) Determine if distinct growth patterns emerge in the Greenland fish that may be related to 'survivors' versus 'non-survivors'.
4) Determine if variations in growth indices are related to oceanographic and ecosystem conditions.
5) Determine if variations in growth indices are related to population abundance and productivity.

5.*************************************

Tracking of Atlantic salmon captured and released at West Greenland

Principle Investigators: Jon Carr (Atlantic Salmon Federation , Timothy Sheehan (NOAA Fisheries Service, and Simon Thorrold (Woods Hole Oceanographic Institute)

Collaborators: tbd

Objectives:

1) Capture and live release of Atlantic salmon at Greenland fitted with pop off satellite tags (either light based geolocation tags or ROAM technology-based tags) to track 1SW non-maturing salmon from Greenland to home waters. Temperature and depth measurement will also be collected.
2) Capture and live release of Atlantic salmon at Greenland fitted with ultrasonic acoustic tags to track 1SW non-maturing salmon nearshore movements and possible migration into home waters.

6.*************************************

West Greenland Fishery Sampling (assumed 2018-????)

Principle Investigators: Timothy Sheehan (NOAA Fisheries Service)

Collaborators: Lawrence Talks (Environment Agency), Phil Davison (Centre for Environment, Fisheries and Aquaculture Science), Gordon Smith (Marine Scotland Science), Niall O'Maoileidigh (Marine Institute), Cathal Gallagher (Inland Fisheries), Gerald Chaput (Department of Fisheries and Oceans), Martha Robertson (Department of Fisheries and Oceans), and Ian Bradbury (Department of Fisheries and Oceans). The work is coordinated via NASCO and is reported to ICES (Working Group on North Atlantic Salmon).

Objectives:

1) Continue the time series of data (1969-2016) on continent of origin and biological characteristics of the Atlantic salmon in the West Greenland fishery
2) Provide data on mean weight, length, age, and continent of origin for use in the North American and European Atlantic salmon run-reconstruction models
3) Collect information on the recovery of internal and external tags

7.*************************************

Genomic based mixed stock analysis of Atlantic salmon fisheries in the North Atlantic

Principle Investigators: Ian Bradbury (Fisheries and Oceans Canada), Gérald Chaput (Fisheries and Oceans Canada), Herle Goraguer, (Ifremer, Saint Pierre Et Miquelon), Martha Robertson (Fisheries and Oceans Canada), Steven Duffy (Fisheries and Oceans Canada), and Timothy Sheehan (NOAA Fisheries Service)

Collaborators: Fisheries and Oceans Canada, NOAA Marine Fisheries Service, United States Geological Survey, Miawpukek First Nation, Nunatsiavut Government, NunatuKavut Community Council, Ifremer (Saint-Pierre et Miquelon)

Objectives:

1) Genetic assignment to region of origin for Atlantic salmon sampled at Greenland (2017-2020)

8.*************************************

Disease sampling at Greenland

Principle Investigators: Jon Carr (Atlantic Salmon Federation) and Kristi Miller-Saunders (Department of Fisheries and Oceans)

Collaborators: Timothy Sheehan (NOAA Fisheries Service)

Objectives:

1) Screening of Atlantic salmon at home rivers and Greenland for a variety of disease agents that may cause chronic infections that reduce the physiological condition and survival

9.************************************

Heart and skeletal muscle inflammation

Principle Investigators: Niccolò Vendramin (Technical University of Denmark)

Collaborators: Timothy Sheehan (NOAA Fisheries Service)

Objectives:

1) Screening for piscine orthoreovirus (widely detected in Norwegian farmed fish), the causative agent of heart and skeletal muscle inflammation (HSMI), which can cause inflammatory lesions of heart and red skeletal muscle.

10.************************************

Atlantic Salmon (*Salmo salar*) in River Kapisillit - the unique spawning population in Greenland

Principle Investigators: Jo Vegar Arnekleiv (NTNU University Museum)

Collaborators: Jan Grimsrud Davidsen (NTNU University Museum), Timothy Sheehan (NOAA Fisheries Service), Ian Bradbury (Department of Fisheries and Oceans), L. Rønning (NTNU University Museum), A. D. Sjursen (NTNU University Museum), G. Kjærstad (NTNU University Museum), and K. Nilssen (Norwegian University of Science and Technology)

Objectives:

1) Describe biological characteristics, levels of genetic diversity, and population structuring of Atlantic salmon sampled from the Kapisillit River (Greenland) from suveys conducted in 2005 and 2012)

11.*************************************

Kapisillit River Atlantic salmon surveys

Principle Investigators: Rasmus Nygaard (Greenland Institute of Natural Resources)

Collaborators:

Objectives:

1) Conduct juvenile surveys of the Kapisillit River to obtain biological characteristics data, biological samples, and population estimates

12.*************************************

High resolution genetic mapping of *Lepeophtheirus salmonis* and relationship to drug resistance

Principle Investigators: Mark Fast (University Prince Edward Island)

Collaborators: Ben Koop (Univeristy of Victoria), Roy Danzmann (University of Guelph), and Timothy Sheehan (NOAA Fisheries Service)

Objectives:

1) Develop a high resolution genetic map for sea lice collected at Greenland for comparison with sea lice collected at aquaculture impacted areas where SLICE treatments have been employed

13.*************************************

Resistant salmon lice (*Lepeophtheirus salmonis*) and the wild salmonids

Principle Investigators: Helene Børretzen Fjørtoft (Norwegian University of Science and Technology)

Collaborators: Timothy Sheehan (NOAA Fisheries Service)

Objectives:

1) To identify the role of wild anadromous brown trout and Atlantic salmon in the dispersal of sensitive and resistant salmon lice within Norway

ANNEX 5: Review of the West Greenland sampling databases, archived tissue samples (scale and tissue samples for genetics), and sampling protocols

Not to be cited without permission of the authors

Atlantic Salmon Research Joint Venture Workshop: Current status of knowledge, data, and research efforts on Atlantic salmon at Greenland: what do we have, what do we need, and what should we do moving forward?

Project Number: GULF2016.21

Working Paper 2018/03

Review of the West Greenland sampling databases, archived tissue samples (scale and tissue samples for genetics), and sampling protocols

Michelle G Fitzsimmons

Contracted to:

Atlantic Salmon Federation

PO Box 5200

St. Andrews, NB Canada E5B 3S8

mgfitzsimmons@gmail.com

Atlantic Salmon Research Joint Venture
Workshop: Inventory review of archived databases and samples
7-9 December 2017

Report by Michelle G Fitzsimmons

Table of Contents

Overview

The purpose of this working paper is to review the database, samples and sampling protocols from the Atlantic Salmon sampling program in West Greenland. This paper will 1) identify the issues/errors in the sampling databases; 2) identify changes made to the sampling databases for fixing errors and data manipulation to produce data summaries; 3) identify any discrepancies between the database and current summaries in the ICES reports; 4) identify and summarize the sampling protocol for the years during the commercial fishery sampling; and 5) summarize the sampling database, genetic assignment database and scale samples in storage.

Issues and Errors within the Sampling Database

There are currently two different databases: one labeled for Commercial Sampling (land-based sampling) and the other for Research Sampling (vessel-based sampling). However, both databases contain sampling types for research and commercial.

Table 1. Annual sampling type in each of the research and commercial databases of Atlantic Salmon (*Salmo salar*) at West Greenland.

	Databases	
Sampling Type	**Research**	**Commercial**
Research Random	5480	6387
Commercial Random	175	10207
Commercial Stratified	0	8320
Commercial Stratified 1.00 to 2.99kg	0	11099
Commercial Stratified 3.00 to 4.99kg	0	5664
Commercial Stratified >= 5.00kg	0	1452
Tag or Handling Mortality	1546	34
Tagged Fish	996	0
Subsample (Random)	0	33
Subsample (Unknown	0	10843

Commercial Sampling Database

The original file is labeled "West Greenland Commercial Sampling Database 1968-2016". The modified data file is labeled "Commercial Sampling.xlsx". It contains 54,041 observations. A field 'ERRORS' was added to the file to identify the errors within the database, and there are 3962 errors in total. The number '1' is assigned if there is an error in the observation and the error is highlighted in yellow. A field 'DATABASE' was added to the file and the number '1' was assigned to these observations to indicate that this data came from the Commercial Sampling database.

Errors

DATA FIELD	CODE	RATIONALE	# OF ERRORS	NOTES
GEAR	0	Code doesn't exist	746	Years 1976, 1977, 1980
DISTRICT	10	Code doesn't exist for WG	1	Year 1984
MONTH	15	Only code for season, not month	85	Year 2006
FL	0	Should be blank	7	
PECTORIALL	0	Should be blank	3546	
WHOLEWT	0	Should be blank	1	
GUTTEDWT	0	Should be blank	9	
MAT	0	Remainder of column is blank	1	Column should be removed
ABNORTAGS	36 & 37	Code doesn't exist	3	
SCALEEDGE	2	Code doesn't exist	4	
RELIABILITY	5	Code doesn't exist	5	
TOTL	0	Should be blank	2189	
GIRTHATCAPTURE	913	All the same number	4356	Only years 2010 and onward

There are no observations for the following fields, and therefore could be deleted from the database (if the Commercial and Research Sampling databases are NOT merged – as some of these fields contain data in the Research Sampling database):

RIVER
GIRTHOPERCULAR
GIRTHMAX
MAT (except one ‘0’; likely an error)
MESHSIZE
WEBBINGTYPE
STANDL
PREDORSALL
DORSALTOADIPOSE
HEAD
POSTORBITAL
LEFTPECT
DORSALFIN
ANALFIN
LEFTPECFIN
LEFTPELVICFIN
VERTEBRAE
ABNORMAL
FIRSTLFGILLRAKERUP
FIRSTLFGILLRAKELOW
FIRSTLFGILLTOT
GIRTHATCAPTURE (contains some ‘913’s; can be deleted if these are errors)

Research Sampling Database

The original file is labeled “Salmon Research Sampling” and contains 15,464 observations. The modified data file is labeled “Research Sampling.xlsx”, and is filtered to contain only the samples for field ‘Class’ = 9 (adult) and ‘Region’ = 1 (West Greenland). The new file contains 8198 observations. A field ‘ERRORS’ was added to the file to identify the errors within the database, and there are 606 errors in total. The number ‘1’ is assigned if there is an error in the observation and the error is highlighted in yellow. A field ‘DATABASE’ was added to the file and the number ‘0’ was assigned to these observations to indicate that this data came from the Research Sampling database.

Errors

DATA FIELD	NUMBER	RATIONALE	# OF ERRORS	NOTES
SAMPLETYPE	2	Code for ‘commercial random’	175	Year 1968
GEAR	0	Code doesn’t exist	428	Years 1969 & 1970

YEAR	1967	Only one observation	1	
MONTH	1	Incorrect time of year	2	From 1981, likely should be 10
LEFTPECFIN	0	Should be blank	1	

There are no observations for the following fields:

RIVER
BLANK
ABNORTAGS
PECTORIALL

For both databases:

- The fields ‘Weight Unit’ and ‘Length Unit’ are not accurate and do not correspond to the actual values listed in the length and weight fields.
- Some of the values for ‘Fork Length’ are in centimetres and others are in millimetres. Some of the values for ‘Whole Weight’ and ‘Gutted Weight’ are in 1/10 kg and others are in 1/100 kg.
- Sea Age and Total Age are not always calculated properly.
- There is field for ‘Dressed Weight’ in the sampling code legend, however this field is not in the database.
- There is a field for ‘Blank’ in the databases, however it is not in the legend and there is no indication of what the numbers represent. There are only 3 observations with data, all from 2010, with the numbers ‘135’, ‘137’, and ‘138’.

Discrepancies Between Database and ICES Reports

The number of samples described in the International Council for the Exploration of the Sea (ICES) reports compared to the current databases differ. Samples off by only a few numbers could be due to errors in the database that need to be fixed, however the larger discrepancies in numbers should be further examined.

Table 9. The number of Atlantic salmon (*Salmo salar*) samples from West Greenland in the sampling database compared to the number of samples reported in the ICES reports, for length (samples with fork length measurements) and scales (samples with age measurements).

			# Samples in Database		# Samples in ICES Reports	
Year	**Sample Type**	**Total Samples in Database**	**Length**	**Scales**	**Length**	**Scales**
1968	Vessel-based	745	735	745	-	-
1969	Vessel-based	407	401	407	212	212
1970	Vessel-based	458	457	452	127	127

1971	Vessel-based	254	253	251	247	247
1972	Vessel-based	1485	1484	1395	3488	3488
1973	Vessel-based	113	113	113	102	102
1974	Vessel-based	837	837	835	834	834
1975	Vessel-based	536	536	535	528	528
1976	Vessel-based	593	593	593	420	420
1977	n/a	-	-		-	-
1978	Vessel and land-based	1063	1057	1049	1047	1047
1979	Vessel and land-based	2685	2678	2670	1981	1981
1980	Vessel and land-based	2208	2204	2193	1595	1595
1981	Land-based	2255	2255	2017	4570	1930
1982	Vessel and land-based	973	960	960	2392	857
1983	Land-based	1988	1988	1984	4896	1815
1984	Land-based	2839	2838	2833	7282	2720
1985	Land-based	2998	2998	2995	13272	2917
1986	Land-based	3509	3509	3498	20394	3509
1987	Land-based	2960	2960	2954	13425	2960
1988	Land-based	2562	2562	2559	11047	2562
1989	Land-based	2237	2236	2235	9366	2227
1990	Land-based	1208	1208	1206	4897	1208
1991	Land-based	1347	1347	1330	5005	1347
1992	Land-based	1684	1684	1682	6348	1648
1993	n/a	-	-	-	-	-
1994	n/a	-	-	-	-	-
1995	Land-based	2469	2469	2467	2045	2045
1996	Land-based	1297	1296	1289	3341	1297
1997	Land-based	282	282	279	794	282
1998	Land-based	406	404	405	540	406
1999	Land-based	617	601	603	532	532
2000	Land-based	491	491	491	491	491
2001	Land-based	2899	2844	2878	4721	2655
2002	Land-based	1316	1314	1310	501	501
2003	Land-based	1835	1820	1810	1743	1743
2004	Land-based	1691	1677	1652	1639	1639
2005	Land-based	767	767	756	767	767
2006	Land-based	1209	1193	1191	1209	1209
2007	Land-based	1125	1115	1109	1126	1110
2008	Land-based	1866	1854	1848	1866	1860
2009	Land-based	1663	1642	1637	1616	1637
2010	Land-based	634	631	607	1210	1213
2011	Land-based	485	482	475	967	965
2012	Land-based	689	689	674	1372	1371
2013	Land-based	578	578	572	1155	1156
2014	Land-based	463	446	384	724	920
2015	Land-based	854	854	839	1708	1704
2016	Land-based	656	655	606	1300	1240

Commercial Fishery Sampling Protocol

According to the Commercial Sampling Instructions, a stratified random sampling technique was used for all sampling during the commercial fishery sampling years (1978-1997, 2001 – excluding years 1993 and 1994 when there was no fishery). Five to ten samples per centimetre group were fully sampled (fork length, gutted weight, scales, etc.) and the remainder of the catch was only sampled for fork length. All samples were to be taken from sorted catches by weight. If the catch was unsorted, all fish would be sampled. See 'West Greenland 1992 Commercial Sampling Instructions' in the appendix for greater detail of the sampling protocol.

Table 10. Sampling type used during the commercial fishery for obtaining Atlantic salmon (*Salmo salar*) samples at West Greenland, 1978-1997 and 2001 (excluding years 1993 and 1994, when there was no fishery)

Year	Sampling Type	Notes
1978	Random	
1979	Random / Stratified / Unidentified	
1980	Random	
1981	Random / Stratified	
1982	Stratified	* issues with sampling
1983	Stratified	* difficulty in obtaining good quality samples
1984	Random / Stratified	
1985	Subsample / Total catch	* missing some weight categories
1986	Subsample / Total catch	* both sorted and unsorted by weight
1987	Subsample / Total catch	* mixed or missing weight categories
1988	Subsample / Total catch	* mixed or missing weight categories
1989	Subsample / Total catch	* unclear if subsamples is by weight
1990	Subsample / Total catch	* unclear if subsamples is by weight
1991	Subsample / Total catch	* unclear if subsamples is by weight
1992	Stratified	
1995	Undetermined	* no information about sampling
1996	Subsample / Total catch	* 3/4 catch removed before sampling began
1997	Subsample / Total catch	* only "good quality" salmon included in subsample
2001	Random / Stratified / Unidentified	

Any documents pertaining to the sampling protocol in each year are attached in the appendix and are summarized below by year.

1978

Research random sampling of 50 salmon in area 1D
Commercial random sampling of 120 salmon in area 1D, 74 salmon in area 1E, and 200 salmon in area 1B.
Total = 444

1979

Random sampling of 215 salmon in area 1E (Frederickshaab)
Random sampling of 464 salmon in area 1D (Godthaab)

Random sampling of 214 salmon in area 1D (Godthaab)
Unidentified sampling of 100 salmon in area 1B (Holsteinsborg)
Unidentified sampling of 293 salmon in area 1B (Holsteinsborg)
Stratified sampling of 156 salmon in area 1B (Holsteinsborg)
Unidentified sampling of 211 salmon in area 1A (Egedesminde)
Total = 1653

<u>1980</u>
Random sampling of 301 salmon in area 1D (Godthaab)
Random sampling of 301 salmon in area 1D (Godthaab)
Random sampling of 383 salmon in area 1B (Holsteinsborg)
Total = 985

<u>1981</u>
Stratified sampling of 1556 salmon and random sampling of 365 salmon in area 1B (Holsteinborg)
Stratified sampling of 2535 salmon and random sampling of 120 salmon in area 1D (Godthaab)
Total = 4576

<u>1982</u>
515 salmon sampled from a research vessel (M.V. Lady Hammond)
A subsample was taken from each weight category (stratified random sampling – see appendix for issues in sampling) of 1144 salmon for area 1B (Holsteinsborg) and the total catch was sampled for 605 salmon for area 1D (Godthaab)
Total = 515 for research and 1749 for commercial

<u>1983</u>
Note: There was difficulty in obtaining good quality samples at Holsteinsborg, as fish were landed at one plant while processed at another and therefore unable to distinguish if it was a total or subsample catch that was being processed.

Stratified sampling of 1790 salmon and random sampling of 98 salmon in area 1D (Godthaab)
Stratified sampling of 1657 salmon and random sampling of 166 salmon in area 1B (Holsteinsborg)
Total = 3711

<u>1984</u>
Random sampling of 6 salmon in area 1D (Godthaab)
Stratified sampling of 569 salmon in area 1E (Frederickshaab)
Random sampling of 44 salmon and stratified sampling of 2530 salmon in area 1C (Sukkertoppen)
Random sampling of 20 samples and stratified sampling of 4125 in area 1B (Holsteinborg)
Total = 7294

1985

Subsample and total catches sampled for area 1D (Godthaab). Some boxes were missing from 1-3 and 3-5kg weight categories for 3 sampling catches

1986

Total catches sampled in area 1E (Frederickshaab). A mix of subsample and total catches sampled in area 1D (Godthaab), 1B (Holsteinsborg) and 1F (Narsaq). Some landings were sorted be weight while others were unsorted

1987

A mix of subsample and total catches sampled in area 1E (Frederickshaab). Some salmon from other landings mixed into sample in 3-5 kg weight category for one sample, and missing 5 kg and over salmon for another sample.
Mostly subsample of catches and one total catch of area 1F (Narsaq)

1988

Subsample and total catches sampled in area 1B (Sisimiut)
Total catches sampled in area 1D (Godthaab)
Subsample and total catches sampled in area 1E (Frederickshaab)
One unsorted subsample catch, sorted subsample and total catches, and a subsample catch with 1-3kg samples missing in area 1F (Narsaq)
Subsample catch in area 1A (Godhavn)

1989

Subsample catch sampled in area 1B (Sisimiut)
Subsample and total catch sampled in area 1D (Godthaab)
Total catch sampled in area 1E (Frederickshaab)

1990

Subsample catch sampled in area 1C (Maniitsoq)
Subsample sampled in area 1D (Godthaab)
Total catch sampled in area 1E (Paamiut)

1991

Subsample and total catch sampled in area 1C (Maniitsoq)
Total catch sampled in area 1D (Godthaab)
Total catch sampled in area 1E (Paamiut)

1992

Stratified sampling of 585 salmon in area 1E (Paamiut)
Stratified sampling of 6249 salmon overall (Reddin et al 1993 [WP 9 - 1992])

1993 & 1994

Commercial fishery was suspended, therefore there was no sampling

1995

No sampling information in files

A random sampling effort was used to obtain a sample of the subsample or total catch from boats. 1168 salmon from area 1C, 680 salmon from area 1D, and 621 salmon from area 1E for a total of 2469 samples. An additional 424 salmon from area 1C were taken but are not included in the year's sample (Reddin et al 1996 [WP 14 - 1995])

* Note that the description of the sampling protocol is identical in all working papers for "Identification and characteristics…." By Reddin et al each year, and is likely a 'copy and paste' description for each document. Therefore this document is not a reliable indication of how the actual sampling was done

1996

Subsample, total, and only partial catches (3/4 shipment removed before sampling began) of 2132 salmon in area 1C (Nuuk)

Total catch sampled of 809 salmon in area 1D (Fiskenaesset)

Total catch sampled of 220 salmon in area 1E (Paamiut)

Total = 3341

1997

Total catch sampled of 128 samples in area 1C (Kangamiut)

Subsample of catch sampled, but only "good quality" salmon, of 666 in area 1D (Nuuk)

Total = 794

1998 to 2000 were Local Consumption Sampling

2001

Random sampling of the subsample catch was sampled for eight days and another eight days did not report sampling protocol, of 539 salmon sampled in area 1D (Nuuk)

Random sampling of the total catch was sampled of 934 salmon in area 1D (Fiskenaesset)

Random sampling of the total catch was sampled of 142 salmon and stratified sampling of the total catch was sampled of 2889 salmon in area 1F (Qaqortaq)

Unreported sampling type of a subsample catch was sampled of 277 salmon in area 1C (Kangamiut)

Database Manipulation

All changes made to the database were done in the program R, version 3.4.2 (R Core Team 2017). The originals files were left untouched and a new file was created with both databases merged (named "Atlantic Salmon West Greenland Database"). A .csv file was created for the merged database, and a .Rdata file was created for reproducing in R. The code for this data manipulation can be found in the Appendix, "Atlantic Salmon West Greenland Database Manipulation".

The following changes were made to the database:

- Both sampling databases were merged.
- The database was checked for duplicate sample observations (2 were identified and were removed).
- The database was checked to confirm the data only contained samples from adult Atlantic Salmon and from the West Greenland region.
- Categorical data was identified as factors and were labeled based on the sampling coding legend.
- A new field was created for Continent of Origin (COO) and the 'Origin' field was used to create the North American and European COO.
- Only one observation for 1967 was in the database and it was removed.
- Sea Age was recalculated to sum 'Virgin sea age', 'Total spawning marks', and 'Sea spawning ages' (4 in total – number of sea years after 1st, 2nd, 3rd and 4th spawning marks).
- Total Age was recalculated to sum 'River age' and 'Sea age'.
- Fork length was converted to cm for all the data.
- Gutted and whole weight were converted to kg for all the data.
- A new 'Whole weight' field was created that is the converted gutted weight multiplied by a conversion of 1.11.

Database Summary

Sampling Database

Table 2. The number of samples of Atlantic salmon (*Salmo salar*) from West Greenland contained in the database by year, including sample type (vessel or land-based), the total number of samples, the number of samples with length and scales, the percentage of North American and European continent of origin and the sample number it was obtained from, and the number of samples for each sea-winter age.

		Samples			**Continent of Origin %**			**Sea-winter Age**					
Year	**Sample Type**	**Total**	**Length**	**Scales**	**North American**	**European**	**N**	**1 SW**	**2 SW**	**3 SW**	**4 SW**	**5 SW**	**6 SW**
1968	Vessel-based	745	735	745	57.89	42.11	722	704	34	5	1	1	0
1969	Vessel-based	407	401	407	50.47	49.53	212	383	22	1	1	0	0
1970	Vessel-based	458	457	452	34.13	65.87	126	430	20	1	1	0	0
1971	Vessel-based	254	253	251	34.55	65.45	246	249	2	0	0	0	0
1972	Vessel-based	1485	1484	1395	37.34	62.66	1390	1313	81	1	0	0	0
1973	Vessel-based	113	113	113	49.02	50.98	102	106	7	0	0	0	0
1974	Vessel-based	837	837	835	42.5	57.5	833	815	19	0	1	0	0
1975	Vessel-based	536	536	535	43.67	56.33	529	522	13	0	0	0	0
1976	Vessel-based	593	593	593	46.7	53.3	591	571	16	6	0	0	0
1977	n/a	-	-		-	-	-	-	-	-	-	-	-
1978	Vessel and land-based	1063	1057	1049	43.61	56.39	1048	1011	30	7	1	0	0
1979	Vessel and land-based	2685	2678	2670	52.05	47.95	2663	2593	60	17	0	0	0
1980	Vessel and land-based	2208	2204	2193	52.03	47.97	2191	2148	44	0	1	0	0
1981	Land-based	2255	2255	2017	57.83	42.17	2011	1873	125	18	1	0	0
1982	Vessel and land-based	973	960	960	52.26	47.74	886	849	103	8	0	0	0
1983	Land-based	1988	1988	1984	43.98	56.02	1835	1522	438	24	0	0	0
1984	Land-based	2839	2838	2833	51.02	48.98	2756	2206	604	22	1	0	0
1985	Land-based	2998	2998	2995	49.69	50.31	2900	2469	501	24	1	0	0
1986	Land-based	3509	3509	3498	52.66	47.34	3456	3062	411	25	0	0	0
1987	Land-based	2960	2960	2954	59.12	40.88	2921	2669	241	42	2	0	0
1988	Land-based	2562	2562	2559	46.34	53.66	2540	2408	134	16	1	0	0
1989	Land-based	2237	2236	2235	51.21	48.79	2187	1868	323	42	2	0	0
1990	Land-based	1208	1208	1206	64.35	35.65	1195	1106	91	9	0	0	0
1991	Land-based	1347	1347	1330	59.68	40.32	1312	1233	93	3	1	0	0
1992	Land-based	1684	1684	1682	55.44	44.56	1405	1510	155	16	1	0	0
1993	n/a	-	-	-	-	-	-	-	-	-	-	-	-
1994	n/a	-	-	-	-	-	-	-	-	-	-	-	-
1995	Land-based	2469	2469	2467	62.47	37.53	2201	2389	60	17	1	0	0
1996	Land-based	1297	1296	1289	63.13	36.87	1207	1203	63	23	0	0	0
1997	Land-based	282	282	279	67.66	32.34	235	265	10	3	1	0	0
1998	Land-based	406	404	405	69.72	30.28	360	394	9	2	0	0	0
1999	Land-based	617	601	603	82.37	17.63	573	584	15	3	1	0	0
2000	Land-based	491	491	491	70.2	29.8	490	482	9	0	0	0	0
2001	Land-based	2899	2844	2878	67.43	32.57	2263	2741	106	30	1	0	0

2002	Land-based	1316	1314	1310	67.47	32.53	501	1282	17	11	0	0	0
2003	Land-based	1835	1820	1810	68.15	31.85	1777	1765	39	5	1	0	0
2004	Land-based	1691	1677	1652	72.73	27.27	1639	1604	27	20	1	0	0
2005	Land-based	767	767	756	76.27	23.73	767	705	40	10	1	0	0
2006	Land-based	1209	1193	1191	71.96	28.04	1191	1131	40	20	0	0	0
2007	Land-based	1125	1115	1109	81.64	18.36	1122	1068	26	15	0	0	0
2008	Land-based	1866	1854	1848	85.97	14.03	1853	1803	40	5	0	0	0
2009	Land-based	1663	1642	1637	91.49	8.51	1621	1521	84	30	1	1	0
2010	Land-based	634	631	607	79.23	20.77	621	594	7	3	2	0	1
2011	Land-based	485	482	475	92.17	7.83	345	447	21	7	0	0	0
2012	Land-based	689	689	674	80.17	19.83	686	633	29	12	0	0	0
2013	Land-based	578	578	572	81.01	18.99	574	544	19	9	0	0	0
2014	Land-based	463	446	384	71.74	28.26	460	361	16	6	1	0	0
2015	Land-based	854	854	839	80.14	19.86	836	820	14	4	1	0	0
2016	Land-based	656	655	606	-	-	-	578	22	6	0	0	0

Table 3. River age and sea age distribution (%) by continent of origin for all North American and European Atlantic Salmon (*Salmo salar*) sampled at West Greenland, 1968-2015.

	North American													
	River Age								Sea Age					
Year	1	2	3	4	5	6	7	8	1	2	3	4	5	6
1968	0.25	19.61	40.44	21.32	16.18	2.21	0	0	94.74	4.78	0.24	0	0.24	0
1969	0	27.1	45.79	19.63	6.54	0.93	0	0	94.39	5.61	0	0	0	0
1970	0	58.14	25.58	11.63	2.33	2.33	0	0	93.02	4.65	0	2.33	0	0
1971	1.18	32.94	36.47	16.47	9.41	3.53	0	0	98.82	1.18	0	0	0	0
1972	0.77	31.85	51.35	10.62	3.86	1.16	0.39	0	90.75	9.06	0.19	0	0	0
1973	2.04	40.82	34.69	18.37	2.04	2.04	0	0	88	12	0	0	0	0
1974	0.86	36	36.57	12	11.71	2.57	0.29	0	95.76	3.95	0	0.28	0	0
1975	0.44	17.33	47.56	24.44	6.22	4	0	0	97.4	2.6	0	0	0	0
1976	0.73	42.55	30.55	14.55	10.91	0.36	0.36	0	93.84	4.71	1.45	0	0	0
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	2.67	31.85	42.98	13.59	6.01	2	0.89	0	94.07	5.05	0.88	0	0	0
1979	4.2	39.91	40.57	11.34	2.8	1.1	0.07	0	95.82	3.17	1.01	0	0	0
1980	5.85	36.27	32.85	16.29	7.92	0.72	0.09	0	97.63	2.37	0	0	0	0
1981	3.52	31.56	37.51	19.03	6.58	1.62	0.18	0	91.83	6.71	1.38	0.09	0	0
1982	1.35	37.67	38.34	15.92	5.83	0.67	0	0.22	89.2	9.94	0.86	0	0	0
1983	3.08	46.98	32.61	12.71	3.72	0.77	0.13	0	64.56	33.33	2.11	0	0	0
1984	4.82	51.68	28.87	8.99	4.61	0.88	0.15	0	68.78	29.94	1.21	0.07	0	0
1985	5.11	40.99	35.74	12.13	4.89	1.06	0.07	0	79.18	19.85	0.97	0	0	0
1986	2.02	39.92	33.37	19.99	4.03	0.67	0	0	83.41	15.82	0.77	0	0	0
1987	3.85	41.37	31.8	16.74	5.83	0.41	0	0	88.01	9.67	2.2	0.12	0	0
1988	5.24	31.27	30.83	20.87	10.74	0.96	0.09	0	92.52	6.37	1.02	0.08	0	0
1989	7.85	39	30.05	15.89	5.94	1.28	0	0	80.09	17.32	2.5	0.09	0	0
1990	8.76	45.28	30.73	12.13	2.43	0.54	0.13	0	91.55	7.67	0.78	0	0	0
1991	5.19	33.59	43.45	12.84	3.89	0.78	0.26	0	93.74	5.87	0.26	0.13	0	0
1992	3.64	37.84	35.24	19.77	3.25	0.26	0	0	86.65	13.09	0.26	0	0	0
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995	2.42	19.02	45.36	22.57	8.75	1.81	0.08	0	96.87	2.4	0.73	0	0	0
1996	1.74	18.72	45.99	23.8	8.82	0.8	0.13	0	92.52	5.38	2.1	0	0	0
1997	1.26	16.35	48.43	17.61	15.09	1.26	0	0	94.97	3.14	1.26	0.63	0	0
1998	0.42	20.42	50.42	22.92	2.92	2.5	0.42	0	97.21	2.39	0.4	0	0	0
1999	2.69	23.47	50.61	20.29	2.93	0	0	0	97.22	1.92	0.64	0.21	0	0
2000	3.16	26.58	38.61	23.42	7.59	0.63	0	0	97.38	2.62	0	0	0	0
2001	1.86	15.18	39.41	32.02	10.84	0.69	0	0	97.76	1.84	0.39	0	0	0
2002	1.54	27.38	46.46	14.15	9.54	0.92	0	0	98.22	1.18	0.59	0	0	0
2003	2.62	28.82	38.93	20.96	7.59	1.08	0	0	96.73	2.77	0.42	0.08	0	0
2004	1.92	19.07	51.92	22.9	3.74	0.46	0	0	96.99	1.29	1.63	0.09	0	0
2005	2.72	21.42	36.3	30.49	8.53	0.54	0	0	92.17	5.91	1.74	0.17	0	0

2006	0.6	13.87	44.63	27.62	12.3	0.97	0	0	93.57	4.05	2.38	0	0	0
2007	1.57	27.77	34.49	26.09	9.18	0.9	0	0	96.46	2.1	1.44	0	0	0
2008	0.9	25.11	51.95	16.78	4.68	0.58	0	0	97.35	2.4	0.25	0	0	0
2009	2.57	30.72	47.26	15.43	3.68	0.35	0	0	93.37	4.65	1.85	0.07	0.07	0
2010	1.96	20.48	48.58	21.79	6.54	0.65	0	0	98.73	0.64	0.64	0	0	0
2011	1.65	37.62	46.53	12.21	1.98	0	0	0	94.82	3.56	1.62	0	0	0
2012	0.37	27.9	40.82	22.85	6.74	1.31	0	0	92.94	5.02	2.04	0	0	0
2013	0.22	32.59	37.47	18.85	9.98	0.89	0	0	94.55	3.7	1.74	0	0	0
2014	0.74	24.54	47.21	21.93	5.2	0.37	0	0	93.17	4.68	1.8	0.36	0	0
2015	0.15	32.57	39.76	21.56	5.81	0.15	0	0	97.72	1.52	0.61	0.15	0	0

European

	River Age								Sea Age					
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**	**2**	**3**	**4**	**5**	**6**
1968	21.55	60.27	15.15	2.69	0.34	0	0	0	97.04	2.63	0.33	0	0	0
1969	0	83.81	16.19	0	0	0	0	0	94.29	5.71	0	0	0	0
1970	0	90.36	9.64	0	0	0	0	0	95.18	4.82	0	0	0	0
1971	9.32	66.46	19.88	3.11	1.24	0	0	0	100	0	0	0	0	0
1972	10.98	71.21	16.65	1.04	0.12	0	0	0	96.21	3.79	0	0	0	0
1973	26	58	14	2	0	0	0	0	98.08	1.92	0	0	0	0
1974	22.93	68.15	8.49	0.42	0	0	0	0	98.96	1.04	0	0	0	0
1975	25.98	53.38	18.15	2.49	0	0	0	0	97.65	2.35	0	0	0	0
1976	23.47	67.2	8.36	0.64	0.32	0	0	0	98.41	0.95	0.63	0	0	0
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	26.24	65.35	8.23	0.17	0	0	0	0	98.14	1.19	0.51	0.17	0	0
1979	23.59	64.81	10.95	0.64	0	0	0	0	98.51	1.25	0.23	0	0	0
1980	25.77	56.89	14.67	2.48	0.2	0	0	0	98.29	1.62	0	0.1	0	0
1981	15.38	67.28	15.74	1.6	0	0	0	0	94.22	5.54	0.24	0	0	0
1982	15.56	56.05	23.46	4.2	0.74	0	0	0	87.23	12.06	0.71	0	0	0
1983	34.7	50.15	12.26	2.39	0.3	0.1	0.1	0	87.06	12.65	0.29	0	0	0
1984	22.71	56.89	15.17	4.16	0.92	0.15	0	0	87.56	12.22	0.22	0	0	0
1985	20.18	61.6	14.91	2.74	0.56	0	0	0	85.68	13.64	0.62	0.07	0	0
1986	19.53	62.5	15.05	2.74	0.19	0	0	0	91.99	7.33	0.67	0	0	0
1987	19.15	62.46	14.75	3.31	0.34	0	0	0	93.97	5.78	0.25	0	0	0
1988	18.43	61.55	17.31	2.26	0.45	0	0	0	95.6	4.18	0.22	0	0	0
1989	17.95	61.71	17.37	2.69	0.29	0	0	0	88.1	10.68	1.12	0.09	0	0
1990	15.94	56.28	22.95	4.35	0.24	0.24	0	0	92.49	7.04	0.47	0	0	0
1991	20.92	47.41	26.3	4.22	1.15	0	0	0	91.49	8.32	0.19	0	0	0
1992	9.29	39.26	44.07	6.73	0.64	0	0	0	95.37	3.19	1.44	0	0	0
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995	14.84	67.3	17.23	0.63	0	0	0	0	97.34	2.18	0.48	0	0	0
1996	15.83	71.1	12.16	0.92	0	0	0	0	95.06	3.82	1.12	0	0	0
1997	4.05	58.11	37.84	0	0	0	0	0	97.37	2.63	0	0	0	0

1998	28.57	60	7.62	2.86	0	0.95	0	0	99.08	0.92	0	0	0	0
1999	27.71	65.06	7.23	0	0	0	0	0	100	0	0	0	0	0
2000	36.5	46.72	13.14	2.92	0.73	0	0	0	100	0	0	0	0	0
2001	15.98	51.21	27.25	4.85	0.71	0	0	0	96.6	3.27	0.14	0	0	0
2002	9.43	62.89	20.13	7.55	0	0	0	0	100	0	0	0	0	0
2003	16.17	57.99	22.09	2.96	0.79	0	0	0	98.93	1.07	0	0	0	0
2004	18.34	57.7	20.54	3.18	0.24	0	0	0	97.03	2.75	0.23	0	0	0
2005	19.16	60.48	14.97	5.39	0	0	0	0	96.69	3.31	0	0	0	0
2006	17.7	54.04	23.6	3.73	0.93	0	0	0	98.8	1.2	0	0	0	0
2007	7	48.5	33	10.5	1	0	0	0	95.57	3.45	0.99	0	0	0
2008	7	72.84	19.34	0.82	0	0	0	0	98.81	0.79	0.4	0	0	0
2009	14.29	59.52	23.81	2.38	0	0	0	0	89.39	9.09	1.52	0	0	0
2010	13.22	52.89	28.1	4.13	1.65	0	0	0	95.93	2.44	0	1.63	0	0
2011	18.52	51.85	29.63	0	0	0	0	0	81.48	14.81	3.7	0	0	0
2012	8.33	65.15	22.73	3.79	0	0	0	0	98.5	1.5	0	0	0	0
2013	3.81	70.48	23.81	1.9	0	0	0	0	97.25	1.83	0.92	0	0	0
2014	5	59	30	6	0	0	0	0	97.09	1.94	0.97	0	0	0
2015	9.88	56.17	27.78	5.56	0.62	0	0	0	98.18	1.82	0	0	0	0

Table 4. Number of Atlantic salmon (*Salmo salar*) sampled at West Greenland by sea-age (1 SW = 1 sea-winter, 2 SW = 2 sea-winter, all other sea-winter ages = ages above 2), Northwest Atlantic Fisheries Organization (NAFO) division and year. Table does not include salmon of unknown age or origin.

	1 SW						**2 SW**						**All other sea-winter ages**					
Year	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**
1968	0	0	0	693	0	0	0	0	0	28	0	0	0	0	0	3	0	0
1969	183	20	6	0	0	3	12	1	0	0	0	1	0	0	0	0	0	0
1970	8	140	8	64	3	0	0	7	0	1	0	0	1	0	0	0	0	0
1971	7	212	25	5	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1972	10	184	575	238	252	53	1	30	28	12	9	1	0	1	0	0	0	0
1973	0	0	0	102	0	4	0	0	0	7	0	0	0	0	0	0	0	0
1974	0	0	0	715	100	0	0	0	0	17	2	0	0	0	0	1	0	0
1975	0	0	0	522	0	0	0	0	0	13	0	0	0	0	0	0	0	0
1976	0	0	0	482	89	0	0	0	0	15	1	0	0	0	0	5	1	0
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	0	350	427	161	73	0	0	11	7	9	3	0	-	-	-	-	-	-
1979	205	630	95	1428	235	0	5	18	0	30	7	0	1	10	1	5	0	0
1980	0	392	575	1181	0	0	0	13	9	22	0	0	0	0	0	1	0	0
1981	0	830	0	1043	0	0	0	33	0	92	0	0	0	4	0	15	0	0
1982	0	180	487	182	0	0	0	63	21	19	0	0	0	4	2	2	0	0
1983	0	675	0	847	0	0	0	229	0	209	0	0	0	10	0	14	0	0
1984	0	1097	697	58	321	33	0	374	190	1	39	0	0	8	4	1	9	1
1985	0	878	203	936	452	0	0	232	22	187	60	0	0	1	1	14	9	0
1986	0	708	0	1014	950	390	0	169	0	124	63	55	0	8	0	5	6	6

1987	0	669	0	791	705	504	0	109	0	68	21	43	0	15	0	9	6	14
1988	312	685	0	680	649	82	27	32	0	33	39	3	1	3	0	9	4	0
1989	0	604	0	649	606	9	0	136	0	122	64	1	0	10	0	13	21	0
1990	0	0	293	541	272	0	0	0	25	46	20	0	0	0	0	7	2	0
1991	0	0	436	457	340	0	0	0	34	41	18	0	0	0	1	0	3	0
1992	0	0	563	0	598	349	0	0	102	0	36	17	0	0	5	0	12	0
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995	0	0	1134	649	606	0	0	0	25	27	8	0	0	0	7	4	7	0
1996	0	0	746	294	163	0	0	0	55	6	2	0	0	0	17	5	1	0
1997	0	0	83	182	0	0	0	0	1	9	0	0	0	0	1	3	0	0
1998	0	0	0	386	8	0	0	0	0	9	0	0	0	0	0	2	0	0
1999	0	123	142	248	0	71	0	4	6	4	0	1	0	1	2	1	0	0
2000	0	0	0	245	0	237	0	0	0	5	0	4						
2001	0	0	282	1414	0	1045	0	0	8	40	0	58	0	0	0	8	0	23
2002	0	0	304	697	0	281	0	0	1	4	0	12	0	0	0	6	0	5
2003	0	0	273	715	0	777	0	0	9	21	0	9	0	0	0	3	0	3
2004	0	0	381	1023	0	200	0	0	6	11	0	10	0	0	0	8	0	13
2005	1	0	146	419	0	139	0	0	7	30	0	3	0	0	0	3	0	8
2006	50	0	115	810	39	117	4	0	5	27	0	4	3	0	1	12	1	3
2007	8	0	175	509	166	210	2	0	4	10	2	8	0	0	2	3	3	7
2008	0	552	0	735	0	516	0	11	0	20	0	9	0	0	0	3	0	2
2009	0	594	38	636	0	253	0	37	3	17	0	27	0	9	0	13	0	10
2010	0	308	0	112	0	174	0	2	0	2	0	3	0	0	0	0	0	6
2011	25	128	0	177	0	117	1	6	0	10	0	4	1	1	0	0	0	5
2012	0	205	276	0	0	152	0	16	9	0	0	4	0	6	6	0	0	0
2013	0	319	143	0	0	82	0	14	2	0	0	3	0	7	1	0	0	1
2014	0	30	175	0	47	109	0	3	9	0	1	3	0	0	3	0	0	4
2015	0	245	436	0	81	58	0	4	7	0	1	2	0	3	2	0	0	0
2016	0	144	258	0	60	116	0	9	4	0	2	7	0	1	2	0	0	3

Table 5. Annual mean whole weight (kg) and fork length (cm) by continent of origin (NA - North American and E – European) and sea age (1 SW – 1 sea-winter and 2 SW – 2 sea-winter) of Atlantic salmon (*Salmo salar*) caught at West Greenland, 1969-2015.

	1 SW				2 SW				1 SW				2 SW			
	NA		E		NA		E		NA		E		NA		E	
Year	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**
1968	2.52	267	3.12	204	4.79	16	5.95	8	61.25	395	65.67	295	75.24	20	80.24	8
1969	3.03	101	3.66	99	5.31	6	5.24	6	64.97	101	68.59	99	76.92	6	77.7	6
1970	2.8	40	3.32	79	4.27	2	4.83	4	64.63	40	68.48	79	75.8	2	80.12	4
1971	2.55	84	3.26	161	4	1	-	-	62.72	84	67.62	160	71.9	1	-	-
1972	2.85	276	3.35	524	5.35	33	5.87	19	63.92	470	67.8	838	79.44	47	83.4	33
1973	3.11	6	4.32	9	-	-	-	-	64.52	44	70.43	51	79.67	6	96	1
1974	-	-	-	-	-	-	-	-	64.1	339	68.13	474	76.79	14	87.4	5
1975	2.49	225	3.32	290	5.29	6	5.82	7	61.77	225	67.48	291	78.17	6	81.14	7
1976	-	-	-	-	-	-	-	-	61.73	259	66.46	310	80.15	13	81.67	3
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	2.76	138	3.45	149	3.66	6	4.44	3	63.67	426	67.83	575	74.06	23	77.86	7
1979	2.81	911	3.3	952	5.47	41	7.19	13	64.2	1325	67.53	1256	76.28	44	86.12	16
1980	2.93	886	3.27	840	6.22	22	5.61	14	64.44	1109	66.73	1033	79.94	27	79.39	17
1981	2.65	1066	3.57	799	6.38	78	7.05	47	61.74	1068	67.79	799	81.07	78	83.91	47
1982	2.74	328	3.24	286	5.79	39	6.63	47	62.64	407	66.28	366	78.58	46	83.36	51
1983	2.4	508	3.01	888	5.24	266	5.4	128	60.84	521	66.17	895	79.17	269	80.08	130
1984	2.56	940	2.86	1170	5.51	419	5.52	165	62.34	966	64.68	1182	79.9	421	79.85	165
1985	2.37	1141	2.97	1248	5.28	286	5.45	199	60.58	1141	65.36	1250	79.09	286	79.29	199
1986	2.7	1494	3.28	1483	6.27	284	5.83	120	62.69	1518	66.79	1505	81.17	288	79.6	120
1987	2.96	1518	3.24	1122	6.29	166	5.98	69	64.53	1520	66.58	1122	81.66	167	80.83	69
1988	2.67	1088	3.46	1302	6.3	75	6.18	57	62.29	1089	67.95	1303	81.45	75	80.82	57
1989	2.61	847	3.07	889	5.67	182	5.62	112	62.46	897	66.15	940	80.21	194	80.37	114
1990	2.62	704	2.75	394	5.93	59	5.63	30	62.8	704	63.76	394	81.34	59	80.2	30
1991	2.45	733	2.68	484	5.92	46	6.13	44	61.66	734	63.67	484	81.2	46	81.8	44
1992	2.57	674	2.83	597	6.31	102	5.96	20	62.22	675	64.23	597	82.86	102	80.75	20
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995	2.37	1330	2.67	802	4.64	33	5.88	18	60.91	1332	63.13	804	73.97	33	80.94	18
1996	2.63	701	2.96	422	5.89	41	5.89	17	62.6	704	64.6	423	79.63	41	79.53	17
1997	2.58	150	2.9	74	6.75	5	6.5	2	62.36	151	64.27	74	81.6	5	85.5	2
1998	2.7	243	2.83	108	3.61	6	4.77	1	61.77	243	62.54	108	68	6	76	1
1999	3.02	422	3.05	90	5.89	8	-	-	63.78	444	63.52	97	76.56	9	-	-
2000	2.47	335	2.81	146	2.58	9	-	-	60.69	335	63.1	146	64.62	9	-	-

2001	2.86	1469	3.02	705	6.32	28	6.1	24	62.95	1466	63.77	708	80	28	79.73	24
2002	2.84	332	2.91	160	5.57	4	-	-	62.54	332	62.04	160	76.6	4	-	-
2003	2.92	979	3.07	508	5.46	26	5.17	4	63.19	1143	64.36	553	74.81	32	78.27	6
2004	3.07	943	3.13	370	4.1	14	5.34	10	64.57	1118	64.87	422	74.34	15	76.15	12
2005	3.18	401	3.3	144	4.33	27	3.09	4	65.88	530	66.39	175	72.73	34	66.7	6
2006	3.06	699	3.19	284	4.81	31	2.97	3	65.26	777	65.26	327	74.06	34	69.35	4
2007	2.85	671	2.82	166	4.79	13	6.2	5	63.51	869	63.2	193	74.06	19	76.39	7
2008	3.03	1487	3.03	237	4.15	37	7.47	2	64.54	1532	63.84	247	71.59	37	85.4	2
2009	3.18	1090	3.22	89	6.06	50	5.86	8	64.88	1350	65.39	118	77.9	67	79.05	12
2010	3.45	427	3.07	105	2.94	3	4.34	3	66.72	465	64.2	118	66.93	3	71.47	3
2011	3.32	291	3.25	22	4.32	10	4.37	4	66.28	291	65.92	22	72.95	11	73.97	4
2012	3.33	443	3.36	116	3.62	24	7.24	1	65.5	500	64.98	131	68.02	27	71.8	2
2013	3.35	424	3.19	106	4.64	17	4.6	2	66.3	434	64.78	106	73.37	17	75.85	2
2014	3.22	235	2.99	89	4.31	10	5.81	2	65.58	247	63.51	98	71.66	10	77.4	2
2015	3.34	616	3.27	159	3.29	10	3.4	3	65.69	642	64.41	162	72.97	10	75.77	3

Genetic Database

Table 6. Inventory of tissue samples collected/available and Continent of Origin (COO) assignments made. Tissues samples collected from 1995-2016 are archived at the US Geological Survey Leetown Science Center in Kearneysville, West Virginia, USA. Tissues samples collected in 2017 are archived at the Fisheries and Oceans Canada, Dartmouth, Nova Scotia, Canada facility. Duplicate genetic material for the years 1995-2016 are also archived at the Fisheries and Oceans Canada, Dartmouth, Nova Scotia, Canada facility. COO results are reported annually by the ICES Working Group on North Atlantic Salmon. Sample sizes are approximate.

Year	Sample size	COO assignments
1995	141	115
1996	200	178
1997	233	220
1998	214	214
1999	423	422
2000	490	489
2001	580	579
2002	1001	501
2003	1779	1779
2004	1688	1688
2005	767	767
2006	1193	1193
2007	1123	1123
2008	1853	1853
2009	1671	1671
2010	1240	1240
2011	964	964
2012	1373	1373
2013	1149	1149
2014	920	920
2015	1674	1674
2016	1302	1302
2017	1345	1000

Table 7. Inventory of Region of Origin (ROO) assignment by NAFO Division. ROO assignments for 1968, 1978, and 1988 are from scale samples and all remaining assignments are from tissues samples. ROO results for the period 1968-2014 are summarized in Bradbury et al. 2016 (ICES Journal of Marine Science (2016), 73(9), 2311–2321). The 2014 assignments using SNPs are presented in a manuscript currently under review (Jeffery et al.). Assignments for 2015-2017 will be presented to the ICES Working Group on North Atlantic Salmon at their 2018 annual meeting.

	NAFO Division							
Year	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**	**Total**	**Comments**
1968				94			94	NA only (12 reporting groups), microsatellite-based
1978		36		38	36		110	same as above
1988				108			108	same as above
1995				96			96	same as above
1996				115			115	same as above
1998				108			108	same as above
2002			94	147		49	290	same as above
2003			191	192		192	575	same as above
2004			192	287		116	595	same as above
2005			130	346	1	100	577	same as above
2006	32		80	615	25	96	848	same as above
2011	53	115		266		215	649	same as above
2012		181	183			182	546	same as above
2013		187	187			172	546	same as above
2014		64	182			182	428	same as above
2014		49	150			133	280	NA (20 reporting groups) and EUR (7), SNPs-based
2015		330	330			90	750	NA only (12 reporting groups), microsatellite-based
2016		250	250			250	750	NA only(12 reporting groups), microsatellite-based
2017		345	348		22	285	1000	NA only, microsatellite-based, sample numbers estimated
Total	**85**	**1557**	**2317**	**2412**	**84**	**2062**	**8465**	

Scale Samples

Scale samples were obtained each year during sampling. Some scales have been used for research purposes and those still available are stored at Fisheries and Oceans Canada in St. John's Newfoundland and Labrador (NL), Canada. The number of scales available for use are not certain, as they are predominantly stored and labeled by envelope (containing approximately 1-12 scales each). The number of exact scales known is only available from 1999 and forward, as they were recently processed for imaging.

Table 8. Inventory of Atlantic Salmon (*Salmo salar*) scales from West Greenland stored at Fisheries and Oceans Canada (St. John's, NL, Canada).

				# scale samples originally obtained per NAFO Division					
Year	**# current envelopes with scales**	**# of scales currently available**	**Sampling**	**1A**	**1B**	**1C**	**1D**	**1E**	**1F**
1968	569	U	Vessel-based	0	0	0	724	0	0
1969	U	U	Vessel-based	195	21	6	0	0	4
1970	228	U	Vessel-based	9	147	8	65	3	0
1971	U	U	Vessel-based	7	214	25	5	0	0
1972	U	U	Vessel-based	11	215	603	250	261	54
1973	U	U	Vessel-based	0	0	0	109	0	4
1974	U	U	Vessel-based	0	0	0	733	102	0
1975	U	U	Vessel-based	0	0	0	535	0	0
1976	784	U	Vessel-based	0	0	0	502	91	0
1977	n/a	n/a	n/a						
1978	1083	U	Vessel and land-based	0	361	437	172	79	0
1979	2346	U	Vessel and land-based	211	658	96	1463	242	0
1980	2378	U	Vessel and land-based	0	405	584	1204	0	0
1981	3880	U	Land-based	0	867	0	1150	0	0
1982	992	U	Vessel and land-based	0	247	510	203	0	0
1983	1186	U	Land-based	0	914	0	1070	0	0
1984	2941	U	Land-based	0	1479	891	60	369	34
1985	3006	U	Land-based	0	1111	226	1137	521	0
1986	3526	U	Land-based	0	885	0	1143	1019	451
1987	2962	U	Land-based	0	793	0	868	732	561
1988	2620	U	Land-based	340	720	0	722	692	85
1989	U	U	Land-based	0	750	0	784	691	10
1990	U	U	Land-based	0	0	318	594	294	0
1991	976	U	Land-based	0	0	471	498	361	0
1992	2099	U	Land-based	0	0	670	0	646	366
1993	n/a	n/a	n/a						
1994	n/a	n/a	n/a						
1995	2892	U	Land-based	0	0	1166	680	621	0
1996	1297	U	Land-based	0	0	818	305	166	0
1997	2696	U	Land-based	0	0	85	194	0	0
1998	U	U	Land-based	0	0	0	397	8	0
1999	U	154	Land-based	0	128	150	253	0	72
2000	491	144	Land-based	0	0	0	250	0	241
2001	2580	155	Land-based	0	0	290	1462	0	1126
2002	1389	134	Land-based	0	0	305	707	0	298
2003	U	176	Land-based	0	0	282	739	0	789
2004	U	164	Land-based	0	0	387	1042	0	223
2005	U	157	Land-based	1	0	153	452	0	150
2006	U	173	Land-based	57	0	121	849	40	124
2007	U	181	Land-based	10	0	181	522	171	225
2008	U	161	Land-based	0	563	0	758	0	527

2009	U	158	Land-based	0	640	41	666	0	290
2010	U	124	Land-based	0	310	0	114	0	183
2011	U	150	Land-based	27	135	0	187	0	126
2012	U	152	Land-based	0	227	291	0	0	156
2013	U	261	Land-based	0	340	146	0	0	86
2014	U	274	Land-based	0	33	187	0	48	116
2015	U	286	Land-based	0	252	445	0	82	60
2016	U	U	Land-based	0	154	264	0	62	126

U = undetermined

ANNEX 6: Inventory of archived tissue collections from Atlantic salmon sampled at the summer feeding area off the coast of West Greenland during the International Sampling Program

Not to be cited without permission of the authors

Atlantic Salmon Research Joint Venture Workshop: Current status of knowledge, data, and research efforts on Atlantic salmon at Greenland: what do we have, what do we need, and what should we do moving forward?

Project Number: GULF2016.21

Working Paper 2018/4

Inventory of archived tissue collections from Atlantic salmon sampled at the summer feeding area off the coast of West Greenland during the International Sampling Program

Mark Renkawitz[1] and Timothy F. Sheehan[2]

[1]NOAA Fisheries Service

Northeast Fisheries Science Center

166 Water Street

Woods Hole, MA 02540 USA

(508) 495-2212

Mark.Renkawitz@noaa.gov

[2]NOAA Fisheries Service

Northeast Fisheries Science Center

166 Water Street

Woods Hole, MA 02540 USA

(508) 495-2215

Tim.Sheehan@noaa.gov

Introduction

Since 1992, various research efforts have been undertaken. The purpose of this document is to provide an overview of samples collected during the annual Fishery Sampling Program at West Greenland. A detailed sample archive may help assist in informing ongoing as well as future sampling priority discussions.

Table 1. Summary of biological samples collected during the annual Atlantic salmon Fishery Sampling Program at West Greenland. The tissue type, purpose of the collection, years, preservation medium, estimated number of samples and last known location of archived samples are presented.

Tissue Type	Primary Purpose	Years	Preservation Type	Number Collected	Archive Location
Adipose	Stable Isotope	2009-2011	Frozen	1008	U. Waterloo (Ontario)
Adipose	Continent/Region of Origin	1995-2016	Ethanol or RNAlater	>23,000	USGS Leetown Science Center (West Virginia) and/or Fisheries and Oceans Canada (Halifax)
Caudal	Stable Isotope	2009-2011	Frozen	1346	U. Waterloo (Ontario)
Dorsal	Stable Isotope	2009-2011	Frozen	1347	U. Waterloo (Ontario)
Heart	Parasite	2003, 2009-2011	Formalin or RNAlater	1251	NOAA Fisheries (Woods Hole)
Intestine	Parasite	2006-2011	Formalin	1436	NOAA Fisheries (Woods Hole
Lipid Steak	Energy Density, Total Lipid, Proximate Composition, Contaminants	2009-2011	Frozen	1192	NOAA Fisheries (Woods Hole), U. Waterloo (Ontario), NTNU (Trondheim)
Liver	Stable Isotope	2009-2011	Frozen	1345	U. Waterloo (Ontario)
Otolith	General Collection	2009-2011	Dry	1186	NOAA Fisheries (Woods Hole)
Otolith	General Collection	2009-2011	Dry	1186	U. Waterloo (Ontario)
Ovaries	Maturity	2009	Bouins Solution	76	Fisheries and Oceans Canada (Moncton)
Scale	Age and Growth Stable Isotope	2002-2016	Dry	20127 1198	Fisheries and Oceans Canada (St John's)
Sea Lice	Population Study Genetics Slice Resistance	2009-2016	Ethanol RNAlater RNAlater	489 751 195	UBC (Victoria), and/or UPEI (Charlottetown), and/or NTNU (Trondheim)
Stomach	Feeding Ecology	2006-2011	Formalin	1451	NOAA Fisheries (Woods Hole)
Stomach	Stable Isotope and Feeding Ecology	2006-2011	Frozen	106	University of Waterloo (Ontario)
Viscera (gill, caeca,	Parasite	2009-2011	Formalin	1142	NOAA Fisheries (Woods Hole)

spleen, kidney)					
Viscera (gill, caeca, spleen, kidney)	Disease	2009-2011	Frozen	1192	Fisheries and Oceans Canada (Moncton)

ANNEX 7: Overview of the Current West Greenland Atlantic Salmon Sampling Program

NOAA FISHERIES

NEFSC

Overview of the Current West Greenland Atlantic Salmon Sampling Program

Timothy Sheehan

December 9, 2017

Overview of Sampling Program

- **Research vessels**
  - 1969-1976
  - 1978-1980
  - 1982

- **Commercial landings (factories)**
  - 1978-1992
  - 1995-1997
  - 2001

- **Commercial landings (markets, businesses, factories*...)**
  - 1998-2000
  - 2002-2017
  - 2014*

NOAA FISHERIES

Contemporary Authority

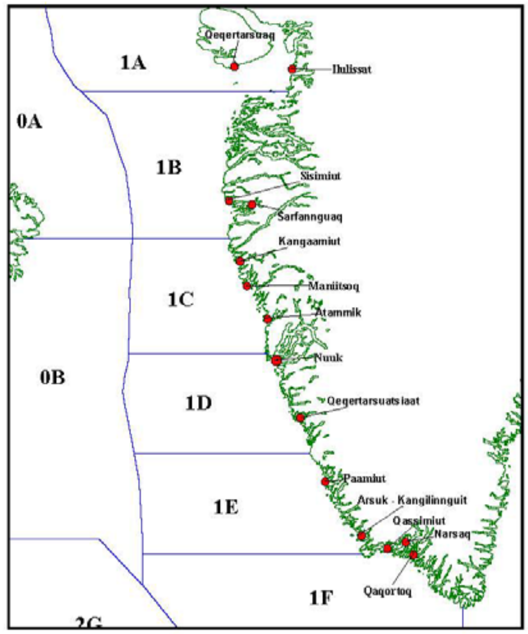
- NASCO's West Greenland Commission
  - Annual agreement (June)
- Data collected:
  - BCs and tags/marks
  - Scales (ageing) and tissue (genetics) samples
  - Other data as requested
- Party commitments:
  - EU (8-10 person weeks, cwt clearing house)
  - CAN (2 person weeks, DNA analysis, ageing, DB maintenance)
  - USA (2 person weeks, Program Coordination, reporting)
  - GRN (assistance)

NOAA FISHERIES

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | NOAA Fisheries | Page 3

Program Coordination

- Spatial/temporal sampling plan
- Focus on:
    - Larger communities
    - Timing of harvest
- Sampling equipment and protocols
    - All (*almost*) essential equipment
- Travel support (*not funding*)
    - Some repeat samplers and many 1st time samplers

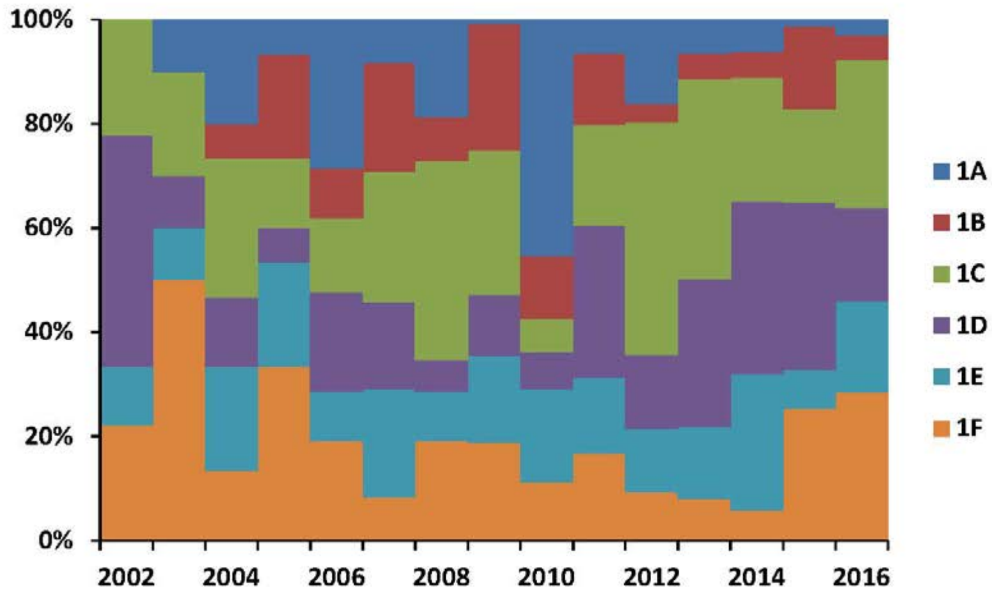


Sampling Options

NAFO Division	NAFO Standard week (15 August – 31 October)											
	33	34	35	36	37	38	39	40	41	42	43	44
1A												
1B												
1C												
1D												
1E												
1F												

NOAA FISHERIES

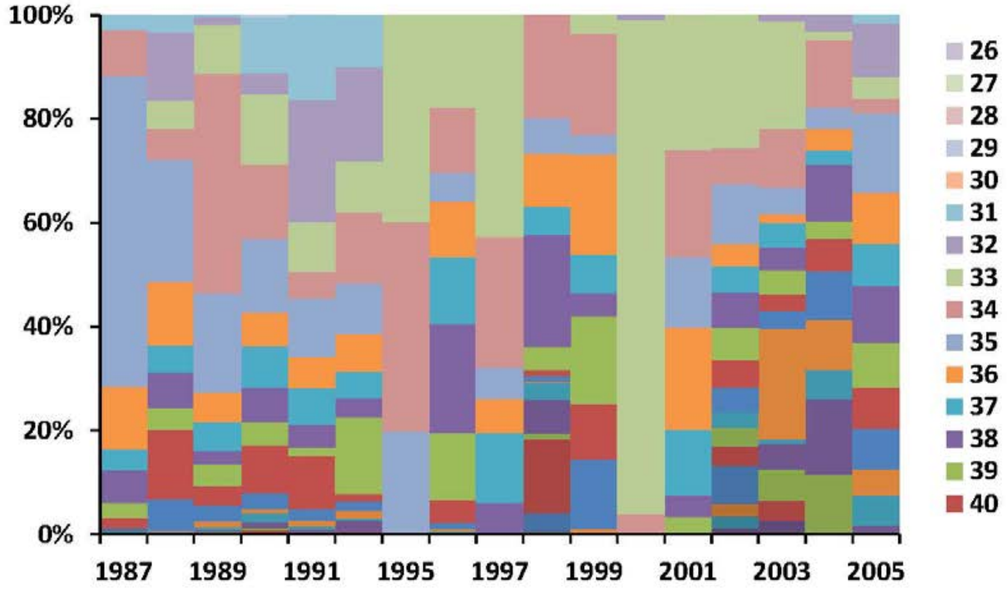
Spatial Dynamics (reported landings)



NOAA FISHERIES

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | NOAA Fisheries | Page 6

Temporal Dynamics (reported landings)



NOAA FISHERIES

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | NOAA Fisheries | Page 7

Sample Numbers by Division

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Grand Total
1A				1	59	10				55							125
1B							568	648	637	272	466	682	65	515	326	475	4654
1C	364	293	405	161	127	181		41			586	302	377	904	545	478	4764
1D	708	750	1061	455	855	525	766	672	230	387						1	6410
1E					41	172							249	169	126	22	779
1F	302	795	225	150	127	238	532	322	398	256	326	172	234	120	317	395	4909
Grand Total	1374	1838	1691	767	1209	1126	1866	1683	1265	970	1378	1156	925	1708	1314	1371	21641

Sample Percentages by Division (reported landings)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A	0%	5%	2%				18%					
1B	18%	18%	12%	84%	37%	67%	41%	229%	104%	10%	24%	121%
1C								26%	6%	9%	35%	26%
1D	193%	52%	30%	139%	76%	237%	30%					
1E		5%	10%							2%	12%	14%
1F	10%	11%	38%	33%	24%	36%	22%	44%	20%	46%	3%	15%
Total	17%	17%	13%	22%	22%	28%	12%	14%	9%	8%	12%	19%

Sample Numbers by Standard Week

Standard week	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
31							69										**69**
32		114	52	7	78	144	20			1							**416**
33	211	515	403	70	3	273	64	110	157				49		56		**1911**
34	440	290	136	259	218	135	174	137	187	37			51		87	32	**2183**
35	269	270	109		363	208	181	379	31	213	72	29	147	10	20	171	**2472**
36	142	453	416	119	128	97	558	305	265	358	328	107	176	134	79	21	**3686**
37	154	158	279	208	51	58	299	96	97	181	197	218	105	329	389	80	**2899**
38	145		185	90	67	42	193	143	172	88	144	308	114	386	331	304	**2712**
39	13		57		126	91	131	360	220	64	189	259	121	338	352	392	**2713**
40				14	36	72	69	141	103	24	448	154	162	216		348	**1787**
41			22		54	5	9	6	16	4		81		169		23	**389**
42		38	32			1	54	6	12					126			**269**
44							45		5								**50**
Total	**1374**	**1838**	**1691**	**767**	**1124**	**1126**	**1866**	**1683**	**1265**	**970**	**1378**	**1156**	**925**	**1708**	**1314**	**1371**	**21556**

Some Sampling Considerations…

- Sampler variability
- Special equipment needed
- Special training needed
- Sample feasibility
- 'Destructive' sampling
- Purchasing salmon
- Preservation requirements
- Hazardous material transport and shipping

Procedures for Issuing Manuscripts in the *Northeast Fisheries Science Center Reference Document* (CRD) Series

CLEARANCE

All manuscripts submitted for issuance as CRDs must have cleared the NEFSC's manuscript/abstract/webpage review process. If any author is not a federal employee, he/she will be required to sign an "NEFSC Release-of-Copyright Form." If your manuscript includes material from another work which has been copyrighted, then you will need to work with the NEFSC's Editorial Office to arrange for permission to use that material by securing release signatures on the "NEFSC Use-of-Copyrighted-Work Permission Form."

For more information, NEFSC authors should see the NEFSC's online publication policy manual, "Manuscript/abstract/webpage preparation, review, and dissemination: NEFSC author's guide to policy, process, and procedure," located in the Publications/Manuscript Review section of the NEFSC intranet page.

ORGANIZATION

Manuscripts must have an abstract and table of contents, and (if applicable) lists of figures and tables. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area" and/or "Experimental Apparatus," "Methods," "Results," "Discussion," "Conclusions," "Acknowledgments," and "Literature/References Cited."

STYLE

The CRD series is obligated to conform with the style contained in the current edition of the United States Government Printing Office Style Manual. That style manual is silent on many aspects of scientific manuscripts. The CRD series relies more on the CSE Style Manual. Manuscripts should be prepared to conform with these style manuals.

The CRD series uses the American Fisheries Society's guides to names of fishes, mollusks, and decapod crustaceans, the Society for Marine Mammalogy's guide to names of marine mammals, the Biosciences Information Service's guide to serial title abbreviations, and the ISO's (International Standardization Organization) guide to statistical terms.

For in-text citation, use the name-date system. A special effort should be made to ensure that all necessary bibliographic information is included in the list of cited works. Personal communications must include date, full name, and full mailing address of the contact.

PREPARATION

Once your document has cleared the review process, the Editorial Office will contact you with publication needs – for example, revised text (if necessary) and separate digital figures and tables if they are embedded in the document. Materials may be submitted to the Editorial Office as email attachments or intranet downloads. Text files should be in Microsoft Word, tables may be in Word or Excel, and graphics files may be in a variety of formats (JPG, GIF, Excel, PowerPoint, etc.).

PRODUCTION AND DISTRIBUTION

The Editorial Office will perform a copy-edit of the document and may request further revisions. The Editorial Office will develop the inside and outside front covers, the inside and outside back covers, and the title and bibliographic control pages of the document.

Once the CRD is ready, the Editorial Office will contact you to review it and submit corrections or changes before the document is posted online.

A number of organizations and individuals in the Northeast Region will be notified by e-mail of the availability of the document online.

Procedures for Issuing Manuscripts in the *Northeast Fisheries Science Center Reference Document* (CRD) Series

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review and most issues receive copy editing.

TO OBTAIN A COPY of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2350) or consult the NEFSC webpage on "Reports and Publications" (http://www.nefsc.noaa.gov/publications/).