WORKSHOP ON SCALE, OTOLITH BIOCHRONOLOGY ARCHIVES (WKBIOARC)

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i Executive summary

The Workshop on Scale, Otolith Biochronology Archives (WKBioArc) met to review and report on issues and solutions for establishing, maintaining, and managing biomineral sample collections to ensure their protection and access for future scientific use. The workshop also examined issues around the management of the data associated with biochronology collections and identified opportunities for international collaboration to support the management of biochronology collections and their use in research.

General guidelines for handling, processing and storing samples and metadata to ensure their long term preservation and accessibility were presented, drawing on the expertise that exists within the museum curation community. An open-source database model and collections management system and associated work-flows were presented. The system utilizes the FAIR (Findable Accessible Interoperable and Reusable) open-data principles, and includes a physical repository, sample metadata catalogue, and image library. The system was developed to organize a collection of salmon scales but can be readily adapted to any biological collection. Core principles for the management of access to collections, the design of databases and the sharing of data were agreed.

A lack of curatorial expertise within the fisheries science community and limited resources (personnel and space) for collections management were seen as the main barriers to the effective preservation of biochronology collections and their use in research. Increased engagement with the museum curation community, which holds a considerable body of shared experience and expertise, is recommended. International collaboration that connects collections across regions allows for more powerful broad scale analyses and offers a strategy for attracting long term funding to support the management and preservation of the collections. To improve the visibility and accessibility of the collections an inventory of the material held across the participating institutes needs to be established.

This workshop is the first step in establishing an international network of biochronology collections.

ii Expert group information

Expert group name	Workshop on Scale, Otolith Biochronology Archives (WKBioArc)
Expert group cycle	Annual
Year cycle started	2020
Reporting year in cycle	1/1
Chairs	Deirdre Brophy, Ireland
	Martha Robertson, Canada
Meeting venue and date	11-12 February 2020, Galway, Ireland, (30 participants)

1 Introduction

The Workshop on Scale, Otolith Biochronology Archives (WKBioArc) had 30 participants that included fisheries scientists, data managers and a museum curator, providing a broad perspective on the issues surrounding the management and use of biochronology collections. Twelve countries/jurisdictions were represented (10 European, 2 North American). Workshop participants provided an overview of their collections; scales and otoliths were the most common structure stored, although fin clips, tissue samples and cephalopod beaks were also featured. Diadromous species (Atlantic salmon *Salmo salar* and European eel *Anguilla anguilla*) were well represented in the collections as were commercial groundfish and pelagic species. Millions of structures are contained within these collections which date from the early 20th century to the present.

While the samples within the collections were primarily taken for the purpose of age determination and stock assessment, they are also being used in genetic, trace element and stable isotope analyses to address a broad range of research questions from fish population structure to climate affects and broad scale ecosystem change.

Across the participants there was a common desire to improve the storage and management of the collections and their associated data through the implementation of standardized protocols. Many hoped to learn from the experience of others and to identify best practice approaches. Problems commonly encountered included a lack of space for storing collections, loss of material due to inadequate curation, lack of resources (particularly personnel) for managing collections, an over reliance on the knowledge of individual personnel regarding the provenance of material. Much of the metadata associated with the collections exists only in paper record and resources for digitizing within centralized databases are difficult to secure.

This report provides an overview of the 13 participant presentations and group discussions. The list of participants, resolution and agenda for the workshop are presented in Annexes 1 – 3, respectively.

2 Summaries of Workshop Presentations

2.1 Session 1: Opening

1. **Overview of the unlocking the archive project**

Deirdre Brophy, Galway-Mayo Institute of Technology (GMIT), Ireland

Hayley Campbell (GMIT), Elvira D'Eyto (Marine Institute), Conor Graham (GMIT), Adam Leadbetter (Marine Institute), Cóilín Minto (GMIT), Niall Ó'Maoiléidigh (Marine Institute), Christina O'Toole (GMIT), Russell Poole (Marine Institute), Elizabeth Tray (GMIT), Louise Vaughan (GMIT), Philip White (GMIT)

The Unlocking the Archive project is a collaboration between Marine and Freshwater Research Centre at the Galway Mayo Institute of Technology and the Marine Institute's Newport Catchment Facility, in Burrishoole, Mayo, Ireland. The project runs for four years (2017-2021) and is funded under the Marine Research Programme by the Irish Government (Grant-Aid Agreement No. PBA/FS/16/03). The project objectives are to: 1) Establish Ireland's first biochronology repository (Irish Fish Biochronology Archive: IFBA); 2) Create digital database of multidecadal growth information, 3) Provide infrastructure to support new research opportunities; 4) Develop capacity in biological and environmental time-series analysis; 5) Develop methods for analysing the composition of scales and otoliths, 6) Investigate responses of migratory fish to environmental change. As an output from the project, an open source collection management system for biochronology archives has been developed (Tray et al., 2020). The Archive project team are using material stored in the collection to: investigate multidecadal trends in the growth of eels and salmon; analyse trace elements and stable isotopes in archived salmon scales; develop methods for detecting stress markers (cortisol) in salmon scales; analyse genetic material from archived salmon scales to investigate temporal trends in population structure and trans-generational relationships between growth and survival. The next steps are to secure resources to support maintenance and expansion of IFBA; to link with similar collections internationally and to stimulate new research activities that are supported by IFBA.

2. **West Greenland Atlantic salmon sampling collection – 50 years**

Martha Robertson, DFO, Canada

Timothy F. Sheehan (NOAA Fisheries Service, USA), Mark D. Renkawitz (NOAA Fisheries Service), Nick Kelly (DFO), Rasmus Nygaard (Greenland Institute of Natural Resources), Niall Ó Maoiléidigh (Marine Institute, Ireland), Ian Russell (Cefas, UK), Gérald Chaput (DFO), Cathal Gallagher (Inland Fisheries, Ireland) and Nora Hanson (Marine Scotland, UK)

A mixed-stock Atlantic salmon fishery that harvests fish from North America and Europe has existed off the west coast of Greenland since the early 1960's. Catches peaked at ~2700 t in 1971 and declined to 58 t by 1997. In response to ongoing conservation concerns since the early 1980s, the Greenland export fishery was closed in 1998 and since then catches have ranged from 9 to 58 t (average 1998-2018 = 28 t). Annual sampling of the Greenland Atlantic salmon harvest has occurred since 1969 (excluding 1993-1994) through international collaborative efforts. Effective management of the resource requires data on annual landings and information on the biological characteristics of the harvest (i.e. length, weight, and scale/tissue samples) to assess the affect of the fishery on contributing stocks. Information on fish age and growth are interpreted from the scale samples and region of origin determined by further analysis of scale or tissue samples. The West Greenland salmon collection currently contains over 60,000 scale samples and 20,000 tissue samples. To continually meet the challenges of Atlantic salmon conservation, restoration, and science-based management, long term monitoring programs and their associated biological collections need to be protected.

Group Discussion:

The first two presentations highlighted examples of large fisheries sample collections accumulated over long periods (50 to 100 years) and the varying conditions in which they are stored and archived. The general group discussion following these presentations highlighted the fact that most sample collections managed by participants are not currently being adequately protected. Workshop participants stated they required guidance on best practices for storing and archiving their collections and then the funding to implement them.

2.2 Session 2: Sample handling processing and storage

3. **The Burrishoole scale and otolith archive**

Elizabeth Tray, Marine and Freshwater Research Centre, Galway-Mayo Institute of Technology (GMIT)/Marine Institute Ireland, Ireland

The Marine Institute has a long term ecological research facility located in Newport, Ireland. The facility contains a multi decadal fish scale and otolith archive which contains thousands of samples, from several diadromous species and from various geographic locations. This collection provided a case study to build an 'open' digital and physical biomineral archive, for past, present and future samples. Issues encountered while developing the system included: several sample identifier codes, unknown samples, degraded and compromised samples, inconsistency in describing sample metadata, and lack of stable long term storage. A mind map was created to visualize the amount of data one fish could produce, and 4 criteria were identified as essential to archiving. The criteria included: known sampling location, known species, known date, and the sample and data needs to exist. Samples are typically grouped in a bundle, which contain similar data as the essential criteria (e.g. all from the same species and season). Physical archiving equipment was purchased to accommodate these bundles/groupings. A label printer was procured, and a persistent unique identifier label was placed on samples prior to deposition into the physical and digital archive. Work is ongoing to archive all samples.

Group Discussion:

The presentation initiated a discussion on the storage details for collections. Questions were asked regarding the physical containers, paper, and adhesives. Details of recommended sample storage practices are included in the following presentation by Paolo Viscardi and in the breakout group summary for physical storage.

4. Sample handling processing and storage: the curatorial perspective

Paolo Viscardi, Natural History Museum, Ireland

Introduction:

Biological specimens represent physical evidence, available for interrogation to ensure the validity and reproducibility of scientific research. Such specimens hold future research potential and may have other uses, such as providing reference material, supporting teaching or training and contributing to science communication.

Stable storage, stable documentation and good governance are key factors in minimizing damage and maximizing access to ensure specimens retain their usefulness. In museums, we refer to this as collections management or curation. There is a considerable body of shared experience and expertise relating to this within the museums sector, much of which is accessible through groups such as the Natural Sciences Collections Association in Europe (NatSCA see natsca.org/) and the Society for the Preservation of Natural History Collections in the United States (SPNHC see spnhc.org/).

Stable storage:

Stable storage helps reduce the risk of specimens being lost or damaged by providing a suitable environment where agents of deterioration can be controlled. Specimens composed of different materials or prepared in different ways for different uses have different storage requirements (e.g. dry bivalve shells for morphometric work have different needs to specimens preserved in ethanol for genetic work). Never use materials that are not stable since deterioration over time can damage specimens and lead to loss of data. Stable materials will usually be referred to as conservation grade or archival and they will have been Oddy tested (see: http://www.conservation-wiki.com/wiki/Oddy_Tests:_Materials_Databases).

Storage areas also need to meet certain requirements, such as only being accessible to bona fide users and having a high degree of biosecurity (pests are a particular problem for biological specimens). They should also be as environmentally stable as possible (particularly with regard to relative humidity, which should be kept below 60% to prevent mould growth) and they should be available for long term use wherever possible.

Stable documentation:

Specimens without information are of limited use, so data should remain clearly associated with specimens as much as possible. This requires appropriately attached and stable labels, with legible and meaningful unique identifiers that refer to archival physical records (registers, notebooks, lists, index cards, etc.), and/or appropriately backed-up electronic databases. Report key overview information about particular collections and/or specimens in relevant publications, with unique identifiers being cited where available. This provides a record useful for future caretakers of the collection while raising awareness of the resource among interested parties (see below).

Labels need to last indefinitely, so use good quality materials (high-rag paper, Resistall paper, Tyvek, etc.). Avoid cheap high-pulp papers, as these are acidic and quickly become discoloured, faded and brittle. Labels need to stay associated with specimens (e.g. sharing a sealed container, attached with cotton, directly written, or fixed to the specimen using an appropriate adhesive e.g. PVA, Paraloid B-72 – See: nautarch.tamu.edu/CRL/conservationmanual/File2.htm)

All marking of labels and specimens should be with good quality ink using an appropriate pen, with clear, unambiguous writing. Inks should be document proof - i.e. light fast, waterproof, and ideally they should also be alcohol resistant and abrasion resistant (Indian ink generally works well). Pencil can be used in some instances, but it can be easily removed through abrasion, so should be treated with caution.

Good governance:

Good governance is vital for maintaining collections. Specimens must be acquired legally, with a clear understanding of ownership, since the owner controls the use. To be accessioned into a collection requires that the title of an object is transferred to the Authority overseeing the collection (as a gift in perpetuity, a purchase or a bequest). The Authority has the right to use or dispose of the specimens as it sees fit and should provide clear guidance in relation to this.

Mishandling is the biggest cause of damage to collections, so people should not use collections without receiving clear instructions and, where necessary, training. Researchers need to know what they can and can't do with collections material (e.g. is destructive sampling allowed? If so, what is the protocol?). Decisions about collections use should rely on good guidance – museums have been doing this successfully for a long time and have well-established standards (see Spectrum: collectionstrust.org.uk/spectrum/).

Sharing your resource:

It is difficult to justify maintaining a resource that is not being used. Sharing information about collections and their research potential encourages use and will often lead to beneficial collaborations. Publications (e.g. seehttp://natsca.org/journal-articles/190), presentations, online databases (e.g. gbmolluscatypes.ac.uk/), connections with research communities, engagement with large digitization projects (e.g. DiSSCo https://www.dissco.eu/, https://www.idigbio.org/, etc.), sharing activity on social media, etc. all provide ways to share what you have with a wide variety of stakeholders and potential collaborators.

Links to resources:

- Natural Sciences Collection Association and the Journal of Natural Science Collections (NatSCA): https://www.natsca.org/ http://natsca.org/journal-articles/190
- The Society for the Preservation of Natural History Collections (SPNCH): https://spnhc.org/
- American Institute for Conservation (Oddy Tests: Material Databases): http://www.conservation-wiki.com/wiki/Oddy_Tests:_Materials_Databases
- nautarch.tamu.edu/CRL/conservationmanual/
- collectionstrust.org.uk/spectrum/
- Distributed System of Scientific Collections (DiSSCo): https://www.dissco.eu/
- Integrated Digitized Biocollections (iDigBio): https://www.idigbio.org/

Ten agents of deterioration:

https://www.canada.ca/en/conservation-institute/services/agents-deterioration.html

http://archaeologymuseum.ca/agents-of-deterioration/

https://www.conservation-wiki.com/wiki/Ten_Agents_of_Deterioration

Group Discussion:

There was much discussion and questions following Paolo's presentation. Workshop participants manage science collections but lack curatorial education or experience. Given the current state of some fisheries collections, this is an apparent oversight in the education of natural scientists and highlights the need for some institutions to acquire curatorial expertise or training.

A more thorough discussion regarding the storage of collections was conducted in a breakout session with Paolo Viscardi and is therefore summarized below.

2.3 Session 3: Data management and accessibility

5. **Unlocking the archive – the data scientist's perspective**

Adam Leadbetter, Marine Institute, Ireland

There are a number of over-arching themes which are currently driving international marine data management best practices. These include the United Nations Sustainable Development Goals; the Blue Economy; the European Commission's INSPIRE Spatial Data Infrastructure; and the FAIR principles of data management (Findable-Accessible-Interoperable-Reusable). The Marine Institute, Ireland has implemented a Data Management Quality Management Framework, accredited by the International Oceanographic Data and Information Exchange of UNESCO's Intergovernmental Oceanographic Commission and aligned with ISO9001 (International Organization for Standardization, https://www.iso.org/home.html). Relevant components of this framework are process flows, documenting how data are collected, curated and preserved; and the Marine Institute's Data Catalogue which provides rich, searchable information about over 400 datasets. A record within the Data Catalogue can be assigned a Digital Object Identifier, allowing a dataset to be cited in the scientific literature.

Through the Unlocking the Archive project, the Data Catalogue has been extended to include details of the samples held within the Irish Fish Biochronology Archive (IFBA). This was achieved through early engagement between the project team and the Marine Institute's Data Management Team; mapping out the information to be stored within the IFBA extension to the Data Catalogue; prioritizing the extensions to the Data Catalogue; and then developing the basic functionality required by IFBA. Where possible, the IFBA database reuses information from the MI Data Catalogue (http://data.marine.ie), and controlled vocabularies available to the community. While the development was done within the custom Data Catalogue software developed at the Marine Institute, other off-the shelf software options were considered and evaluated before this approach was settled on. Either approach requires some customization and development, and each individual organization must assess which approach suits them best. A key consideration is the ability to extract the underlying data and make it available to any other system should a data migration be required.

Online resources:

https://librarycarpentry.org/Top-10-FAIR/2018/12/01/research-data-management/

Group Discussion:

Group discussion focused on the software options for database storage. Participants discussed their experience with different software packages and the limitations they have encountered with them (e.g. requirement for system upgrades, inability to export data to a csv file format). Adam provided a general overview of the web based data management system Drupal used by the Marine Institute.

6. Developing and refining workflows for archiving biological samples

Siobhán Moran, Marine Institute, Ireland

Introduction:

Process flows, also known as workflows or flowcharts, are a method of visually documenting the stages involved in performing a certain procedure. Symbols are used to show each of the steps required to create deliverable outputs such as products or services from the inputs.

The Marine Institute Data Management Quality Management Framework

The Marine Institute has established a Data Management Quality framework which is under accreditation by the International Oceanographic Data & Information Exchange (IODE) since 2019. It follows the ISO 9001:2015 standard for Quality Management

Process flows are part of the suite of documentation required for each dataset in the framework. They are developed using Microsoft Visio software and use the Business Process Model and Notation (BPMN, http://www.bpmn.org/) visual modelling language, a popular and intuitive graphic that can be easily understood by all users (Figure 1).

Horizontal lines break the process into what are termed 'swimlanes' on the page, which can categorize the dataset into different general areas (e.g. data collection, data storage etc.).

The swim lanes and basic shapes of the notation together help illustrate the flow and of the data and tell the story of a particular dataset, from collection to product delivery.

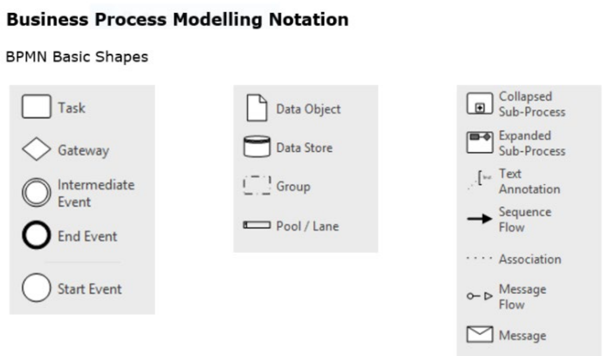


Figure 1: The basic shapes of Business Process Modelling Notation (http://www.bpmn.org/)

Why Process Flows?

It should be remembered that process flows should be developed in tandem with Standard Operating Procedures (SOPs). The process flow readily shows the steps involved in the life of the data, but it is in the SOPs where the detail is found, explaining the nuances of how each step is carried out.

The time taken to develop and refine a process flow varies on the complexity and expertise of the creator. While some training may be required, there are many online tutorials, and it doesn't take long to be able to master the basics of putting a flow together for a dataset.

Process flows have many benefits, and only a few disadvantages, which can be easily overcome. Advantages of using process flows include:

- **Visual Clarity** – Multiple progresses and their sequences can be visualized in a single document. It can lead to highlighting if any steps are unnecessary, or which areas can be improved.
- **Instant Communication** – The instant visual understanding can help clarify for team members what they need to do step by step, and can help communicate the logic of a system to all involved.
- **Effective Coordination and Efficiency Increase** – Recording a process visually can help identify and eliminate unnecessary steps, thereby saving time and resources
- **Effective Analysis** – Problems can be analysed more effectively. Each step in the process is identified using clear symbols
- **Problem Solving** – Process flows can break a data flow into easily definable parts.
- **Proper Documentation** - Digital flowcharts serve as a good paperless documentation, which is needed for various purposes, making things more efficient

Some disadvantages of process flows are that they can become crowded and clumsy in the case of a more complex system. However, a way to address this is to bring the overall flow up a level, and use sub-processes to show the more detailed steps in a particular area. Time and resources are also required to initially create the process flows, and keep them up-to-date.

Group Discussion:

Group discussion focused on the various software programmes that can be used to develop process flows. The program Microsoft Visio was suggested as it has the Business Process Modelling Notation (BPMN) built in but any vector type software could be used for process flows (e.g. Coral Draw, Powerpoint).

The development of the process flow in conjunction with the database was discussed as being an optimal approach. However, in most cases the process flow is designed after the completion of the database.

7. The Irish Fish Biochronology Archive

Elizabeth Tray, Marine and Freshwater Research Centre, Galway-Mayo Institute of Technology (GMIT)/Marine Institute Ireland, Ireland

A database was developed to house biomineral sample metadata, and archive location. Database requirements identified were: it must be user friendly, scalable, interoperable, secure, and low cost. In total, four database engine options were researched as potential avenues for the database. It was decided to develop a custom database as an extended feature of the MI Data Catalogue (run using Drupal), which complies with EU INSPIRE regulations, and also meets the FAIR (findable, accessible, interoperable, reusable) data principles (Wilkinson et al. 2016). Spatial data from Ireland's Water Framework Directive were used to model sampling location. Controlled vocabularies were used from FishBase, World Register of Marine Species, and the International Council for Exploration of the Seas. The database is continuously being developed for improved efficiency, and updated with samples and new sampling locations.

Group Discussion:

Database Fields

There was discussion about what fields should be included in a database. Subjective fields not based on data should be avoided. If they are included, an associated field should also be included to indicate the method used. For example, whether the life history (i.e. multi-sea-winter or one-sea winter) was interpreted by "external appearance" or "scale reading". Sex is also a common field but the reliability of this field if determined by "external appearance" is very poor. Internal examination or genetics is more reliable. Therefore, a method field for sex should also be included.

All data that is on a fish scale envelope should be included. Even incorrect data would have value for determining error rates. The database field should include a unique identifier for information taken directly form the envelope (e.g. "envelope_lifehistory", "envelope_age" etc.). A comments field can also be added for random information placed on the envelope.

Methods for exporting data for other researchers was also discussed. The database should be built with the ability to select individual fields of interest and export them effectively.

Imaging and Age methods

There was discussion regarding the information that should be included on the master image of a scale/otolith. Master images must include a scale bar for reference to ensure accurate measurements between images and researchers. The image should be annotated with the metadata necessary to link the sample image to a specific database (e.g. Database Name and Sample ID Number). Include the image number if multiple images of the same sample are taken, include an image number. All aging and growth measurement markings should be done and saved on a separate copy of the master image.

Costs of Equipment/Resources

The costs of equipment and resources was discussed (e.g. database construction, sample boxes, staff time etc.). The Irish Fish Biochronology Archive spent €10,000 on sample boxes and label supplies. Participants indicated that the use of placement students/bursars/crowd sourcing can be used to make the initial process of archiving collections more efficient and cost-effective. Teaching archiving methods and providing experience can be used as a valuable educational tool.

Database hosting and Common Databases

There was discussion about making data available to the public. In many cases the database is made public but with a limited number of fields. The public would be able to find out what samples are available within a collection but not all the metadata associated with the sample.

There was discussion about building an international fish database. The challenges associated with this would be the incompatibility of languages used by various institutions, inability of some institutions to provide data and the need for a host organization. It was suggested that ICES could host a database rather than giving one country the responsibility.

Rather than aiming for one database, it was suggested that we should focus on developing consistent structure and terminology between our individual databases.

2.4 Session 4: Research supported by biochronology archives

8. The COLISA archive

Jean-Christophe Aymes, National Research Institute for Agriculture Alimentation and Environment (INRAE), BRC COLISA, France

Jean-Christophe Aymes, Mélanie Martignon, Quentin JOSSET & Frédéric Marchand

COLISA, for Collection of Ichtyological Samples, is a Biological Resource Center (BRC) formed by the reunion of four long term collections of fish biological samples from INRAE and OFB. It documents research on the evolutions of aquatic ecosystems and their populations in face of global and local changes. It is integrated into two national Research Infrastructures, the IR LIFE (Living in Freshwater and Estuaries) and IR AgroBRC (an agronomic federation of French biological resource centers).

It currently covers some 30 fish taxa (mainly salmonids), with different samples types (mostly scales, tissues and otolith), which are originated from numerous rivers and Lakes in metropolitan France, but also from French southern territories (Kerguelen Islands). It follows international referential and meet high standards about data quality and traceability. In that regard, the BRC COLISA aims for an ISO9001 international quality certification.

The main goal of COLISA is to promote and ease scientific valorization and collaboration around these extremely valuable collections, by a facilitated access and guidance to the sample catalog and metadata. It can be accessed online at: https://www.colisa.fr

Group Discussion:

The discussion focused on the time and resources that were required to develop the COLISA archive. The project was a large collaborative effort including a dedicated database expert and took ten years to complete from the initial collection of random boxes to the current structure and database. Undertaking the ISO certification process helped in developing a standard database structure, prioritizing tasks and the overall management of the project (team structure, meetings, decision-making).

9. The CEFAS otolith and scale repository

Ewan Hunter, The Centre for Environment, Fisheries and Aquaculture Science (Cefas), United Kingdom

A personal account of the Cefas archive of biomineralized materials was provided, with a focus on marine fish otoliths, starting with an overview of Cefas capacity and long history in age determination. My own expertise is in behavioural ecology, and having commenced my career at Cefas leading large fish-tagging programmes using archival tags to describe the movements of species including plaice, rays and sea bass, I have become increasingly interested in using otolith chemistry from tagged fish coupled with data from archival tags from the same individuals to describe the fish' lifetime movements. Cefas in Lowestoft has existed since 1902, and some material in our archive dates back to this time. Otolith boxes, housed on rolling shelving, are arranged in time order, and occupy approximately 220 m of shelf-space. Material ranges from 'unsorted age-determination material' and 'paperwork' to 'survey otoliths and resin blocks'. The archive is a MEDIN accredited Fisheries Data Archive Centre (FishDAC). Recent material in the archive is more voluminous and is more systematically ordered than older otoliths (the oldest otoliths date to the 1920s, and are relatively rare). Scales are housed in metal filing cabinets at the back of the store. Metadata for processed survey otolith samples have been entered on a Cefas database back to 1977, however these database is not linked to physical specimens, and as no catalogue exists for the physical archive, any request for archive material must be retrieved manually. Examples of current Cefas research using otoliths and scales were given, including 3D imaging, population dynamics using otolith and scale chemistry, and a novel study using otoliths to describe the exposure history and dynamics of liver cancer in flatfish in UK waters.

Group Discussion:

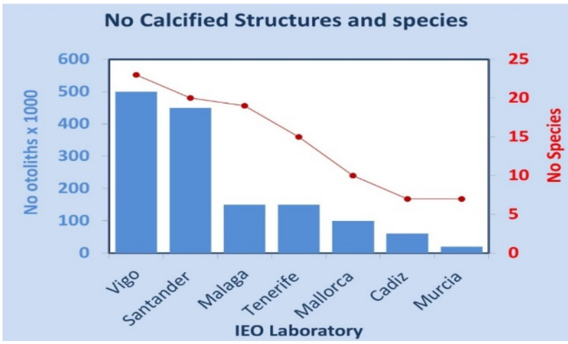
Participants discussed the value of these collections in research studies investigating historical factors affecting fish growth and survival and predicting the future affects of climate change. The value of collections for engaging the public and communicating a message was also highlighted.

It was also noted that for some species, older otolith collections may not be useful for age or growth interpretation as the light and dark areas may no longer be apparent as in some cases the otolith becomes all white. However, these collections are still valuable for biochemical or genetic research.

10. Otolith collections held by IEO (Spain)

Javier Rey and Carmen Gloria Piñeiro, Spanish Institute of Oceanography (IEO), Spain

The Spanish Institute of Oceanography (IEO) is a public research body, dedicated to research in marine sciences, especially in relation to scientific knowledge of the oceans, the sustainability of fishery resources and the marine environment. The Fisheries Area aims to know the status of stocks of fish, molluscs and crustaceans of interest to Spanish fleets. Spanish fleets operate around the entire world, in every ocean. The research is directed to the knowledge of the biology of the species, to the evaluation of their populations, to the biotic and abiotic factors that influence them and to the fishing activity itself. The IEO has a collection of 1.4 million of calcified pieces (mainly otoliths) of 56 species and 65 stocks collected from 1976 to 2019. This collection is increased every year through an exhaustive biological sampling that, by mandate of the EU, is conducted by the IEO in the Atlantic and Mediterranean waters for ageing purposes. The main species represented are large, tropical and small tuna, demersal species, small pelagic, cephalopods and bivalves. , Most of the CS collections and growth experts are concentrated in seven of the nine IEO coastal laboratories. Consequently, each CS collection, as well as its associated metadata, is managed by species- specific area teams, located in different laboratories. Although currently different storage methods and processes are used for each species, common samples storage, classification and metadata format protocols would be desirable to facilitate access to IEO CS collections in future. Also, IEO (together with Malaga University engineers) has developed free software "OTOLab", designed to facilitate the ageing of fish from different CS, as well as otolith morphometric shape analysis (http://www.ieo.es/en/web/ieo/investigacion).



Group Discussion:

Group discussion focused on the importance of data validation for otolith age determination. Many institutions have their own internal quality control standards (i.e. multiple trained and experienced readers, each sample interpreted by two or more readers with consensus) but standards between institutions is very limited.

Participants highlighted the ICES SmartDots program that provides data tools for otolith age interpretation and guidelines for international sample exchanges and workshops.

11. Calcified Pieces Storage in IFREMER institute

Kelig Mahé, French Institute for Ocean Science (IFREMER), France

In 2005 the Ifremer Institute, (certified ISO 9001), established the National Sclerochronology Centre at Boulogne-sur-mer. Since then, the 40 000 calcified pieces (otoliths, scales, illicia, vertebrae, spines, opercula etc. from more 30 marine species (teleosteens and elasmobranchs) that are sampled annually in all French waters are sent to this research centre. For each calcified piece, a calibrated image and growth measurements (radius and all distances between the nucleus and the growth rings) are generated at Boulogne-sur-mer. Following this step, there are two archives: a physical one, in a building dedicated to archiving, and a digital one of images and measurements that is held on a server. All of these data are available in a national database identifying fishery data, individual characteristics and sclerochronology data (ageing, reader, used calcified structure, method, etc.). In this French database, there are more 500 000 individuals sampled from 1971.

Group Discussion:

Participants discussed the computer storage space required for image collections and the need for an off-site backup. High-resolution black and white images are not large but can add up for large collections. 3D imaging is becoming more common but take up more computer space.

12. Archived fish scales at NINA and their use in research

Kjetil Hindar, Norwegian Institute for Nature Research (NINA), Norway

The Norwegian Institute for Nature Research (NINA) is a research foundation with 275 employees, over 60 of whom work on salmon. NINA's legacy is from 1 July 1912 when Professor Knut Dahl was appointed head of the new State of Norway's research on freshwater and anadromous fish. In 1910, professor Dahl published that the age and growth of salmon and trout could be read from their scales. NINA's scale archive contains over 300 000 scales, collected from 1909 to the present. Approximately 30 000 scales are collected annually by NINA, Rådgivende Biologer, Veterinary Institute and LUKE (from rivers that cross the Norway and Finland borders). The focus of the collections is on wild Atlantic salmon, escaped farmed Atlantic salmon, (sea-run) brown trout, (searun) Arctic charr, and recently, pink salmon. Scales are held in envelopes, which Anglers fill out with catch and fish statistics. NINA adds a QR code, reads scales from plastic impressions, extracts DNA, and stores data in a salmon database that allows coupling of scale reading and genetics. There are currently 316 081 entries in the database. Scale envelopes are stored in cardboard boxes stored in a dry environment; metadata describing the contents of each are written on the box for easy retrieval of samples. Salmon scales are sources of DNA for both basic and applied science. The scales have been used to find genetic markers that discriminate between native wild salmonids and domesticated conspecifics and to locate genomic regions that are important for life history and growth traits (Barson et al., 2015; Karlsson et al., 2016). Analysis of scale growth patterns has facilitated the discrimination of salmon of wild and farmed origin and the investigation of spatial and temporal variation in the incidence of farm escapes (Diserud et al., 2019; Glover et al., 2019). Genetic analysis of scale material allows farmed to wild genetic introgression to be quantified and the genetic affects of restocking to be evaluated (Karlsson et al., 2016; Hagen et al., 2019). Affects of introgression on growth rates and life history traits have also been investigated by pairing genetic analysis with the measurement of scale growth patterns

(Bolstad et al., 2017). Research that relies on scale reading and DNA is funded by international (SalSeaMerge, EU) and national (SeaSalar) funding bodies. Archiving is difficult to fund, having tried the Research Council of Norway twice with no success. Scientists at NINA welcome opportunities to seek funding through International collaboration.

2.5 Session 5: Collaboration and funding-Horizon scanning

13. Supports needed and the funding landscape

Deirdre Brophy, Galway-Mayo Institute of Technology (GMIT), Ireland

Globally, millions of biochronology structures are held within museums, universities, government institutions and private collections. The collections are difficult to access by the scientific community due to their disparate nature and the lack of standardized protocols for their curation. Yet they hold enormous potential for addressing societal challenges such as climate change, food security and sustainability. If the benefits of biochronology collections to research are to be fully realized, a range of supports are needed. These include physical space to house the collections, personnel to manage the collections, IT infrastructure to ensure effective management of the associated data. Overlaid on these basic foundations, international networking activities are needed to connect biochronology collections around Europe/globally, facilitate the sharing of knowledge regarding their management and use in research and develop collaborative research. Many collections accumulate as a by-product of scientific monitoring programs and short term projects, and long term curation is rarely a central objective. The lack of long term funding to support the preservation and management of biochronology collections threatens their accessibility to the scientific community. Funding mechanizms which could support the development of a network of biochronology collections include the EU COST action programme and H2020 European Research Infrastructure programmes. Such mechanisms could provide medium term (4-5 years) funding to support the better integration and management of collections across Europe and increase their accessibility. This would ultimately serve to demonstrate the value of the collections for ecosystem monitoring and assessment of climate affects and their relevance to core management objectives at a European level.

Group Discussion

There was a general consensus that the lack of long term funding to support the management of biochronology collections is a threat to their preservation and use in research. It is often easier to secure funding for short term projects that use the material to address specific research questions than to get resources for collections management. Many within the group have first-hand experience of the difficulties associated with securing financial support for collections management. The main requirements are technical personnel to curate the collections and manage the associated data (including database design) as well as physical space to house the collections. The collections can be used to address policy relevant questions (e.g. examining affects of climate change or fisheries induced change), this importance perhaps needs to be communicated more effectively so that the collections are prioritized for core funding and recognized as an important piece of research infrastructure (like a research vessel for example). The importance of international collaboration was recognized and the workshop was seen as an important first step in establishing a network for future collaboration. Collaborative initiatives can connect collections across different areas, allowing for more powerful broad scale analyses. There was also a feeling among the group that the organization of individual collections needed to be improved before a larger collaborative effort to manage collections was established.

3 Summaries of Workshop Breakout Sessions

Workshop participants were broken into four groups on Day 1 to discuss specific topics related to biochronology collections. An overview of each group discussion was presented to all workshop participants on Day 2. Written summaries of these discussions are provided below.

Group 1: Physical Storage

The group discussed the benefits of "conservation grade" and "archival quality" products for the preservation of collections and the need for appropriate storage space. The products mentioned below can be found online by searching for "archival storage materials" or "preservation equipment" or contact your local museum and ask what materials they suggest and where they source them.

Labelling:

Paper: acid-free paper will not discolour or break down as readily as standard paper products

Ink: archival quality pens or artist pens are lightfast, waterproof, alcohol resistant, and abrasion resistant (e.g. Indian ink)

Pencil: dark 2B lead are good but can rub off over time, archival quality pencils are also available

Printing labels: use archival quality printers, labels and ink

Hand written labels: use clear basic letter shapes

Testing products to ensure they will work for your collection is recommended (withstand water, alcohol, abrasion, light etc.).

Fasteners and Adhesive:

String: cotton string or ribbon (undyed): can be used to keep bundles of samples together or hold labels to samples. Elastic bands should not be used as they break down over time and become brittle.

Metal fasteners (paper clips and staples): should not be used as they generally rust, stain papers and break apart over time. Non-corrosive, rustproof staples or stainless steel paper clips could be used.

Tape: archival quality, acid-free, will not discolour or degrade over time

Adhesive: PVA glue (polyvinyl acetates) or Paraloid B-72, acid-free, clear and flexible. Egg white can be used for some applications.

Storage Facility:

Climate controlled storage facilities with stable temperature and humidity levels are not often available in scientific institutions.

In most storage facilities, protecting collections is about risk management. There are 10 primary threats to collections termed the "Ten Agents of Deterioration". Detailed information regarding how to identify and mitigate these threats can be found online.

https://www.canada.ca/en/conservation-institute/services/agents-deterioration.html

http://archaeologymuseum.ca/agents-of-deterioration/

https://www.conservation-wiki.com/wiki/Ten_Agents_of_Deterioration

The main factors to be aware of and mitigate within any storage space are:

Temperature and humidity:

- Knowledge of the temperature extremes and fluctuations and relative humidity (should be less than 60%) are necessary to determine the type of storage containers that should be used. Dehumidifiers can be used to control humidity where feasible (Perkins-Arenstein, 2002).

Light:

- Direct sunlight or bright lights will break down plastic and paper products. Collections should be stored in the dark.

Pests:

- Insects, rodents and bats should be monitored and controlled. Kits available online. search "archival pest control"

https://museumpests.net/ https://www.mail-archive.com/pestlist@museumpests.net/

Security:

- Access to the collection should be restricted to authorized personnel

<u>Storage Containers</u>:

Collection samples should be completely dry prior to placing in any storage container.

Paper: Paper storage boxes can be used in climate controlled storage facilities.

Plastic: Airtight plastic containers should be used where temperature or humidity is not controlled. A packaged desiccant should be placed in the box to absorb any residual moisture and replaced as necessary (a piece of paper towel is better than nothing). Plastics should be stored in the dark as they are light sensitive and become brittle over time. Clear plastic has a shorter lifespan than darker plastics. Select the containers best for your collection but ensure the type of plastic is durable and has a long lifespan.

Group 2: Management Structure around samples

The group discussed the main challenges facing the effective management of samples in biochronology collections and proposed approaches to dealing with these challenges.

The long term storage of samples can be threatened by a lack of resources (primarily human resources) and space. This could be addressed by coordinating efforts to secure resources across the ICES community; promoting biochronology collections as a European/International research infrastructure network requiring centralized and long term support. Limitations to space available for storage could be addressed by partnering with museums.

Mechanisms to facilitate access to collections must ensure that:

- Sufficient numbers of samples remain preserved within the collection and not exposed to destructive sampling.
- Use of samples in research is coordinated and well documented; analyses are not unnecessarily duplicated
- The intellectual input of scientists involved in generating data associated with the collections is properly acknowledged when the material or data are used in research
- Outputs from research based on the collections add value to the collection

With regards to the management structure surrounding access provision:

- There should be a clear decision-making structure (a scientific committee) for granting access to collections, with representation from those involved in collecting and managing the material
- Criteria for granting access should be clearly defined with a focus on ensuring quality of the research outputs
- Procedures for access already in place in museums can provide a template for developing procedures specific to biochronology collections.
- Applications for access should be subject to peer review
- Access to material should be subject to a data sharing agreement which promotes open access to the resulting data, facilitates input from managers of collections to data interpretation, acknowledged through co-authorship and ensures that new data generated from the research feeds back into the collections database

Group 3: Coming up with common database design

The specific requirements and design of each biomineral samples database architecture will vary depending on the needs of the research facility and its scientists. The group discussion focused on the general requirements for initiating the database design.

The database design should:

- Follow the FAIR (Findable-Accessible-Interoperable-Reusable) principles of data management (Wilkinson *et al.* 2016)

Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. The FAIR Guiding Principles for scientific data management and stewardship. Sci Data 3, 160018 (2016). https://doi.org/10.1038/sdata.2016.18

- Consist of a relational paradigm which allows for future enhancement and extensibility of the attributes assigned to each sample within the database. When possible, globally unique identifiers should be assigned to the samples, and a standardized scheme could be adopted for these identifiers (such as the International GeoSample Number, IGSN).
- Use standard controlled vocabularies to fill out as many of the fields as possible. This ensures consistency in spelling and syntax across the database, and if using well-recognized controlled vocabularies, across databases in different organizations. Many of these controlled vocabularies are already widely accepted by the fisheries scientific community (including those published by ICES, FishBase, and the World Register of Marine Species).

- Not be driven by reporting to external standards, but should capture all the data and metadata the repository has need for and can manage. However, the database should be designed such that reporting becomes possible to international and global repositories (such as the Global Biodiversity Information Facility- GBIF, using Darwin Core; or to the INSPIRE Spatial Data Infrastructure in Europe through the Observations and Measurements standard).

Group 4: How will data be released and shared

Management & Release of Data

We considered the granularity of biochronology archive data available at institutional, national and international scales. We identified that different processes for different species in different geographies were sometimes being applied nationally at an inter-institutional level, but that it should be relatively straightforward for institutions to make available existing metadata with little additional work (and deal with inconsistencies and standardization at a later date). Some multi-location institutes currently apply different lab-specific procedures. We acknowledged that for a single species, it isn't always possible to get a clear picture of the material currently available at the European level.

Between the institutions present, it was clear that each is slowly dealing as best they can to backfill their catalogues with data incrementally with the gradual introduction of historical metadata. The limitation in all cases is resource – available time/manpower.

The nature of probable requests for data were discussed – these are likely to consist mainly of direct requests for data or specimens for research by other scientists/collaborators. Other requests may be 'interrogative' (number, species, geography) of specimens, and we are sometimes subject to 'Freedom of Information' (FOI) requests. These are relatively straightforward to deal with by directing enquiries either to a master dataset (e.g. DATRAS) or to national/institutional online catalogues. DATRAS and the Data Collection Framework (DCF) were consistently cited as exemplars of good practice in the management and release of data.

Some participants highlighted problems in sharing data internally, including the use of different file formats, and they were concerned that data should not be released freely without an explanation of the conditions/terms of reference around the data collection, and wider salient conditions. Clear identification of a coordinating data 'owner' was seen as important.

There was a split in the group between those favouring the full release of data into the public domain, and those uncomfortable with fully relinquishing control. It was noted that there were established means of maintaining a degree of control over existing datasets, including the assignation of datasets with DOIs or the publication of datasets in data journals. It was further recommended that in addition to DOIs, instructions on the recommended citation details of the dataset can easily be included as the top line in the data download spreadsheet (e.g. currently used by INRAE).

Finally, we briefly discussed the importance of developing a protocol/flow chart to provide clear, logical guidance in decision-making when deciding whether or not data/specimens can be released.

4 Next Steps and Recommendations

As was evident from the workshop presentations and discussions, the collections of calcified structures held by fisheries institutes internationally are comprehensive about their taxonomic, temporal and geographic coverage. The material represents the substantial investment that has been made in biological sampling programs to support the assessment of commercial fish stocks. Research that draws on these collections adds value to this investment; as new methods for analysing the structure and composition of calcified structures and associated data develop, the potential insight that can be gleaned from the collections increases. With many extending back to the early 20th century, the collections provide a window to past ecosystems and are of huge value to studies of how fish populations respond to drivers such as climate change and fishing pressure. To ensure that the full value of the collections can be realized by the scientific community, they must be properly preserved and made accessible.

The workshop identified that resource limitations (primarily personnel and space) present a barrier to ensuring that collections of calcified structures are adequately protected for future scientific use. Although many of the staff working directly with the collections recognize their value and are committed to their preservation, they often lack the required curatorial expertise and time to manage the collections for posterity. Also, when there is pressure for space within facilities, collections may be moved off site, making them less accessible, or they may even be disposed of.

As a measure to improve the visibility of the collections and to increase recognition of their value when requesting funding for managing these assets or using them in collaborative research, it is recommended that an inventory be created to hold the metadata (species, years, geographic areas, numbers and types of structures) and identify the locations and contacts for each collection. A draft template for the collection of the metadata are included in Annex 4. The most efficient approach for completing this inventory may be through a request to the ICES expert groups whose member institutes are the custodians of these collections. The inventory could then be housed in the ICES metadata catalogue and updated annually by the Chair of the participating ICES expert group.

It is suggested that the fisheries science community make use of the considerable body of shared experience and expertise that is available within the museums sector, much of which is accessible through groups such as the Natural Sciences Collections Association in Europe (NatSCA see natsca.org/) and the Society for the Preservation of Natural History Collections in the United States (SPNHC see spnhc.org/).

To address resource limitations, funding mechanisms appropriate to developing the collections as an integrated research infrastructure will be identified and targeted by a consortium involving workshop participants and other collaborators. The aim is to establish and then expand a network of biochronology collections for fish and other organisms. Researchers using collections to address specific research questions should include resources for cataloguing and archiving the material and the data generated in their research proposals. This will help to ensure that the research adds value to the collections and contributes to their protection and preservation.

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Annex 2: Resolution

2019/WK/EOSG01 The **Workshop on Scale, Otolith Biochronology Archives** (WKBIOARC), chaired by Deirdre Brophy, Ireland, and Martha Robertson, Canada, will be established and meet in Galway, Ireland, 11–12 February 2020 to:

a) Review and report on issues and solutions for establishing, maintaining and managing biochronology archives of biomineral samples (scales, otoliths and other bones, etc.) to ensure protection and access of these valuable archives for future scientific use (Science Plan codes: 3.1, 3.3, 3.5);

b) Establish common database designs that facilitate the sharing and co use of the archives across national boundaries (Science Plan codes: 3.1, 3.5);

c) Promote and report on international collaboration opportunities and potential new projects using archive material and data in order to address regional scale questions and to develop new scientific understanding and quality advice (Science Plan codes: 3.1).

WKBIOARC will report by April 2020 for the attention of the HAPISG, WGNAS, WGBAST and WGDIAD.

Supporting information

Priority	ICES Working Group on North Atlantic Salmon (WGNAS) and NASCO's International Salmon Research Board (IASRB) have recognized the high value of archival scale collections that, as a result of advances in analytical methods, can now be used for genetic, stable isotope and growth studies. Additional information may be obtained in future in response to further advances in analytical methods. There is some concern that these collections may be lost unless appropriate arrangements are in place to archive them and ensure their safe storage so that they may be available for analysis. It was recognized that even if the samples themselves are not lost, the information (metadata) accompanying them could be lost or damaged while in storage. As consequence, there is a very high priority for this workshop.
Scientific justification	There are several new initiatives with regard to biomineral archive collections (fish scales and otoliths) and the establishment of permanent and secure repositories, which are being developed by individual parties. (Unlocking the Archive, Ireland, National Funding 2017 to 2020): SAMARCH (EU Interreg UK/France, 2017 to 2022): Norwegian Research project (National Funding 2016 to 2018): (AST/Freshwater Biological Association (FBA)). Individuals who are leading these projects have encountered common issues such as, sample degradation, missing data, database scalability, etc. Issues to be considered in this workshop: Recognizing there is a century or more of samples in some institutes with various recording methods, solutions surrounding sample/data storage methods from the workshop attendees need to be reviewed and reported in the context of: Preservation and restoration of older samples. Physical housing (rehousing) and storage of large and old archives.

	In order to coordinate the shared use of scale archives and data between institutions for the future, current scale/otolith preparation, mounting, and data recording practices need to be reviewed and a standardized approach outlined with respect to: Aligning approaches and work flows for scale/otolith processing and reading efficiency. Standardizing procedures for logging samples, including guidance on best practices and use of standard nomenclature that is universally accepted among the scientific community (inter-operability). Cataloguing geographic descriptions of source or origin: uniform spatial data recording methods for samples will aid in identifying samples spatially and provide an overview of data across national sampling programs. Improving data extraction methods and exchange of data across various databases to aid interoperability and ease of analysis of data across workers and jurisdictions. Improving comparability of datasets for cross calibration. Standardizing database platforms if possible. Describing procedures for storing images that can reduce space and cost, and improve identification and management of archives samples for contribution to studies requiring destructive sampling (isotope analyses, genetic analyses, etc.). Documenting attribution to ensure credit to many workers involved in collecting and maintaining archives. Ensuring data integrity after funded projects are complete.
Resource requirements	None
Participants	This workshop is open to scientific and technical users of biochronocology material, particularly those who have archives or long term (>20 years) of material and data.
Secretariat facilities	None
Financial	No financial implications
Linkages to advisory committees	ACOM, Various fish stock assessment groups
Linkages to other committees	SCICOM, HAPISG, IEASG, WGDIAD, Workshop on Optimization of Biological Sampling (WKBIOPTIM)
Linkages to other organizations	NASCO

Annex 3: WKBioArc Agenda

2019/WK/EOSG01 The Workshop on Scale, Otolith Biochronology Archives (WKBIOARC), Galway-Mayo Institute of Technology (Room 509) Galway, Ireland, 11–12 February 2020

Tuesday, February 11th		
Session 1: Opening		
9:15	Registration and welcome	
9:30	Overview of the unlocking the archive project	Deirdre Brophy
9:50	The West Greenland salmon scale archive	Martha Robertson
10:10	Tea and Coffee	
10:40	Round table introductions	
Session 2: Sample handling processing and storage		
11:50	The Burrishoole scale and otolith archive	Elizabeth Tray
12:10	The curatorial perspective	Paolo Viscardi
12:30	Lunch : City of Galway Restaurant, GMIT	
2:00	Open floor discussions/break out groups : issues and solutions for managing repositories	
Session 3: Data management and accessibility		
2:45	Unlocking the archive – the data scientist's perspective	Adam Leadbetter
3:05	Developing and refining workflows for archiving biological samples	Siobhán Moran
3:25	The Irish Fish Biochronology Archive	Elizabeth Tray
3:45	Open floor discussions/break out groups: establishing common database designs	
5:00	Day 1 End	

Wednesday February 12th		
Session 4: Research supported by biochronology archives		
9:15	The COLISA archive	Jean-Christophe Aymes
9:30	The CEFAS otolith and scale repository	Ewan Hunter
9:45	Otolith collections held by IEO (Spain)	Javier Rey
10:10	Tea and Coffee Break	
10:40	Calcified Pieces Storage in IFREMER institute	Kelig Mahé
11:00	Archived fish scales at NINA and their use in research	Kjetil Hindar
11:20	Open floor discussions/break out groups: International collaboration opportunities	
Session 5: Collaboration and funding - Horizon scanning		
12:00	Overview of funding avenues	Deirdre Brophy
12:10	Open floor discussions/break out groups	
12:30	Lunch: City of Galway Restaurant, GMIT	
2:00	Open floor discussions/break out groups: potential new projects/funding proposals	
4:30	Day 2 End	

Annex: 4 Template for metadata inventory

Species	ICES area	Life stage	Start year	End year	Structure	Condition	Institute	Contact person
Example metadata entry								
Clupea harengus	7J	adult	1980	ongoing	otolith	Whole, in resin	Some institute	some-body@someinstitute.com