Editorial

Welcome to the second Volume of the *Journal of Natural Science Collections*: a Journal for you who work with natural science collections everyday. I hope that the articles in this Volume prove to be interesting, and useful for all.

There are a large variety of topics covered in this Volume. The first article examines protocols for destructive sampling in natural history specimens, providing a nice case study and destructive sampling forms for researchers that can be adapted for your own institution. A paper examines the fascinating natural history displays of old and new, with surprising results. An interesting article can assist with the museum curators decision to lend specimens for research, where the article examines whether Micro-CT scanning affects DNA in specimens. Conservators share their methods of cleaning a beautiful scrimshaw, with an interesting history. Old natural history models are hidden away in many a museum storeroom, so a nice article about remedial conservation of 19th century models will motivate me to pull out mine and have a look! Colleagues in Berlin write about their enormous database project cataloguing incredible backlogs; a challenge faced by all of us! The Natural History Museum, London look at their tube worms, which were first discovered 100 years ago. The final article outlines the detailed conservation of a seriously damaged herbarium album.

The articles presented here aim to provide guidance for working with natural science collections. If colleagues are wanting to undertake specific conservation work on areas in their collection, and are unsure as where to begin, please do contact one of the NatSCA committee who will be able to advise.

All the articles from Volume 1 are now available for free to view on the NatSCA website (www.natsca.org). Please also have a look at the NatSCA blog, which has more informal write ups of views, book reviews and conferences (http://naturalsciencecollections.wordpress.com/).

I am very excited about the NatSCA 2015 conference and AGM. The theme is all about how we use traditional and social media to talk about our collections. Social media will be big, as will how museums get involved with television and radio. Another method of promoting your collections, and raising awareness with colleagues, is by writing articles for journals. Please do keep on sending in your articles for the new Journal. Not only do they promote your collections and work, but they also assist as inspiration and guidance for your colleagues!

Jan Freedman (Editor)
December 2014

Submitting an article

The *Journal of Natural Science Collections* will be published once a year around December. We encourage our members working with natural history collections to submit articles for the Journal. The articles can vary from conservation to specific collection projects.

We would like the articles to be beneficial to all our members to assist with their day to day work. The Journal may also be an outlet for users of the collections, and researchers to publish findings they have discovered whilst working on natural history collections.

Full guidelines for authors can be found on the NatSCA website:

www.natsca.org

For submitting posts for the NatSCA Blog, please contact blog@natsca.org

If you are interested in submitting an article, and may be unsure if it is suitable for the Journal or the Blog, please contact the Editor or the Assistant Editor:

Editor: Jan Freedman
Plymouth City Museum and Art Gallery
email: Jan.freedman@plymouth.gov.uk
tel: 01752 30 4765:

Assistant Editor: David Notton
Natural History Museum, London
email: d.notton@nhm.ac.uk
tel: 0207 942 5974

View From The Chair

2014 has been an active one for the natural sciences collections community as a whole, galvanised in part by the excellent joint conference of the Society for the Preservation of Natural History Collections, Geological Curators Group (GCG) & NatSCA in Cardiff. At the meeting a Memorandum of Understanding was signed by all three organisations and this important official recognition of our joint purpose was Clare Brown's last act as Chair of NatSCA, before handing the mantle to yours truly. Clare's level-headed and incisive leadership has set a high standard that will be hard to match!

Over the past year NatSCA has had something of a shake-up of how we work as an organisation. We have had Arts Council England funded posts that have allowed us to reassess our strategy and refine our focus on those things that matter the most, while improving our infrastructure. Our website and blog have been beautified and are now regularly updated (be sure to check out our jobs page), while our use of social media has been revolutionised.

We have made all of our back-catalogue of publications freely available, now indexed at the article level and searchable on Google Scholar. Carter & Walker's *Care and Conservation of Natural History Collections* book has also been scanned and made freely available on our website, thanks to the efforts of our previous Secretary and newly appointed Archivist Paul Brown.

We have also been busy organising workshops and conferences, running a variety of events in 2014 and planning many more for 2015-16, including our AGM in Bristol on 21st-22nd May, which will look at the use of traditional and social media in getting our collections out to wider audiences. This is gearing up to be an exciting meeting that will undoubtedly attract a lot of interest, so book early!

To support people attending training and meetings we have also been making bursaries available, which we will continue to administer, but with quarterly deadlines. We have also granted funds from the Bill Petit Memorial Award towards two projects - the Grant Museum of Zoology's Quagga specimen's conservation and curation of the Discovery deep-sea samples at the National Oceanography Centre, Southampton.

NatSCA has also been working hard to represent both big and small natural sciences collections at a national level in the Natural History Consortium, Linnean Taxonomy & Systematics Committee and *#NatureData* project. To help support this work we have undertaken the *Natural History Near* You crowdsourcing project to find all of the natural history collection in the UK and provide some basic information about where they are, what they hold and how they can be accessed. So far we have over 300 collections on our map, with more still being added. If you know of a collection, make sure it's on the map! http://www.natsca.org/NHNearYou

As you may expect, our recent increased activity, along with rising prices, has put pressure on our funds. We have been trying to reduce our costs and find new ways of generating income, so our committee has shrunk from 20 to 13 in order to reduce the amount spent on travel for meetings and we have been seeking additional funding for our activities from grants. Unfortunately we have also recognised a need to increase our membership fees by £5, taking the cost of membership for a waged individual member to £20. This is our first price increase in over 10 years and it is below the average inflation rate for that period, so we hope it won't sting too much!

In order to improve our efficiency in processing payments and bookings - and to make things more convenient for members - we have introduced PayPal and Eventbrite, although we still have a paper booking and payment option available for those who need it.

So as you can see, we've been keeping busy, with more thanks to the hard work of coordinators Justine Aw and Russell Dornan and our excellent team of volunteers Sam Barnett, Glenn Roadley, Rachel Jennings, Emma Louise-Nicholls and Isla Gladstone.

Here's to an even more active 2015!

Paolo Viscardi
December 2014

New patron for NatSCA

Sitting alongside Professor Alice Roberts and Professor Iain Stewart, the committee is delighted to introduce a new patron for NatSCA. Our three patrons are skilled science communicators and strong advocates for the importance and value of natural science collections.

Ben Garrod

"Museums act as passports, permitting visitors to access a world which would otherwise only be available to few. They are hubs of diversity and each one allows us not only an invaluable glimpse into the past but also an exciting peak into the future. The days where museums were quiet sanctuaries for the educated and wealthy are thankfully gone and have been replaced by exciting, vibrant and dynamic havens of learning, inspiration and fun."

Ben Garrod is an evolutionary biologist and broadcaster. His research focuses mainly on island evolution in primates. He has presented the award-winning BBC series *Secrets of Bones* and is a regular presenter on the *One Show*. Museums and their collections feature heavily in Ben's research and TV work, and, increasingly, in his free time.

Partner Organisations

NatSCA are proud to work closely with a number of key associated societies. At the conference in Cardiff, 2014, we signed a Memorandum of Understanding along with the GCG and SPNHC, demonstrating our joint purpose and ensuring closer working relationships between us all.

The Geological Curators Group (GCG) was established in 1974 to improve the state of geological collections and curation. This is done through meetings, training, conferences and publications.

For more information, please visit:

www.geocurator.org

The Society for the Preservation of Natural History Collections (SPNHC) is an international society which aims to improve the preservation, conservation and management of natural history collections to ensure their continuing value to society.

For more information, please visit:

www.spnhc.org

Eggs is eggs: A case study in destructive sampling and analysis of museum natural history specimens

John R. M. Stewart[1], Isla S. Gladstone[2a] & Matthew J. Collins[1]

[1]BioArCh, Biology S-Block, University of York, Heslington, York, YO10 5DD

[2]Bristol Museums, Galleries & Archives, Bristol Museum & Art Gallery, Queens Road, Bristol, BS8 1RL
previously at York Museums Trust

[a]corresponding author: isla.gladstone@bristol.gov.uk

Received: 9th Sept 2014
Accepted: 15th Dec 2014

Abstract

Where destructive sampling of museum natural history collections is proposed, the needs of current research must be balanced against preservation for future use of a finite resource. This paper presents a case study of an interaction between researchers at the University of York and curators at York Museums Trust (YMT) regarding a request by the former for destructive sampling from YMT's historic bird egg collection. We draw attention to reasons for success and share an approach to managing a destructive sampling request in a regional museum useful to both researchers (in preparing requests) and curators (in assessing and acting upon these).

Keywords: Birds; Museum egg collections; Biomolecular archaeology; Destructive sampling

Introduction

This case study represents an interaction between researchers at the University of York and curators at York Museums Trust (YMT) surrounding a request for destructive sampling from YMT's historic bird egg collection. The paper summarises key questions raised and shares an approach to managing destructive sampling from the perspective of both curator and researcher.

Collecting the eggs of wild birds was a popular pastime during late Victorian and Edwardian eras, when many collections numbered in the thousands (Manson-Bahr, 1959; Lightman, 2000). However, with introduction of the Protection for Birds Act 1954 this practice became illegal. Museums now represent the best accessible source of material for researchers wishing to study the eggs of non-domestic species (Russell, *et al*., 2010).

The last few decades have seen significant development in scientific research techniques, and the rate of progress in molecular technology has been particularly advanced in recent years. These new developments have opened up exciting new scientific possibilities, leading to a concomitant increase in requests for destructive analysis of museum specimens. These possibilities enhance still further the existing long-term value of natural history collections. However, factors driving research and requirements to destroy a specimen for analysis, in whole or part, are often not easily compatible with rigorous curatorial care of collections and their preservation for the future.

Stewart, J. R. M., Gladstone, I. S., & Collins, M. J. 2015. Eggs is eggs: A case study in destructive sampling and analysis of museum natural history specimens. *Journal of Natural Science Collections.* **2.** pp. 4-12.

In particular, a desire for high-profile publication in the competitive environment of professional science can lead to a bias in requests for destructive analysis of the most high-impact and irreplaceable specimens, including of extinct or endangered species. Whilst large samples may be required from specimens before analytical techniques are refined, advances in technology over relatively short timescales can facilitate analysis of much smaller samples. For example, it is now possible to recognise morphologically indeterminate bones and other materials using protein sequencing and select these for DNA analyses (Buckley, *et al*., 2009; Richter, *et al*., 2011; van Doorn, *et al*., 2011).

Background to the case study

The aim of the researchers' project was to produce a proteomics-based system for species identification of archaeological eggshell fragments, based on highly sensitive mass spectrometry and peptide mass fingerprinting. Eggshell is common on many archaeological sites but the large volume of material often found, combined with an inability to rapidly identify it, has previously precluded its systematic archaeological interpretation (Stewart, *et al*., 2013). The interaction between the research project and YMT arose due to the need for a reference database representing the eggs of as many species as possible.

The first step in the process was addressing a number of key questions prior to submitting a sampling request, as follows:

What does the YMT egg collection contain – can it support the proposed research?

As for many museums, incomplete documentation of this historic collection presented an immediate barrier to exploring this question in detail. The nucleus of YMT's egg collection, a taxonomically-arranged collection of specimens made by the Yorkshire Philosophical Society, plus a large historic collection made by collector William Cooper, had previously been accessioned and catalogued to specimen or clutch level. However a series of collections in small cabinets or boxes, made by individual collectors or containing specimens of mixed provenance, remained largely undocumented. To overcome this, the researchers were supported in creating an 'Excel' catalogue of the undocumented collection (approximately 4,000 individual egg specimens) for curatorial review and import to the Museum's computerised object management system (Adlib). Unaccessioned specimens were not accessioned at this stage, so that curators could consider whether some specimens should be separated into a new destructive sampling collection or be put forward for disposal, following Russell, *et al*., (2010).

What is meant by 'destructive' analysis in this context? Nature, size and extent of sampling

The research team invested time testing and refining analytical techniques using commercially available eggs to establish the smallest possible amount of material required for robust results (Stewart, *et al*., 2013). The protein content of eggshell is high, and sufficient concentrations could be recovered from very small (<1mg) pieces of shell. In addition to size of individual sample per specimen, the number of samples needed per specimen and number of specimens needed per species were considered. Based on analyses of domestic species, it was found that proteomic content is remarkably consistent both between and within the eggshell of any given species. This minimises the number of specimens required; for specimens not common in the collection, and for which only very limited sampling is possible, a single sample from a single specimen will suffice. However, sampling from two or three specimens taken by different collectors was preferred as a cross-check on taxonomic identification, which relied on the specimen's label.

What type and resolution of data are required for the research?

For this research only taxonomic identification was required, to the level of species.

Is specimen condition important?

The physical condition of the specimens was not important for this research. This included eggs affected by 'Byne's disease' - a chemical reaction which degrades the eggshell, caused by an acidic environment plus high relative humidity and characterised by a crystalline surface efflorescence (Carter, 2000). Whilst damaging to some research and display functions, the researchers ascertained that this degradation did not affect the preservation and recovery of the intra-crystalline proteins (preserved within calcium carbonate biominerals of the eggshell) required for this project.

Formalising and processing the request

Request form, policy and procedure

To capture and assess the request, a policy document and a destructive and invasive sampling request form were developed for internal museum use, based on advice from colleagues in other museums and guidelines in Carter & Walker (1999). These are shared in Appendix 1 and 2.

The request form is divided into a number of parts:

Part 1 Details of people and places/institutions involved.

Part 2 Project details:

- a project outline helps summarise and advocate the project internally/externally and assess the strength and significance of the research question.
- asking justification for sampling helps question why collections, and your collections in particular, are required (non-destructive alternatives may be possible).
- detail of sampling methodology and analysis, including proven success of the technique and the researcher's experience, enable ex-

tent of destruction and likelihood of success to be assessed (new techniques may be approved depending on strength of research); the curator should feel able to ask for evidence in the form of papers, descriptions or photographs if unfamiliar with techniques.

- maximising sample use for future research where this is not destroyed.

Part 3 Specimen details – plus a framework of issues to consider per specimen

Part 4 Terms and conditions: it is important to clarify these in writing to ensure expectations are addressed at the start of a request and that maximum benefit is obtained from the research and for the collection.

The completed request form was initially assessed by the curator with final approval from the Collections Management team.

Assessing which specimens are suitable for destructive analysis

Published precedence exists for a method of physically pre-filtering egg collections to aid requests for destructive sampling at the Natural History Museum, London (Russell, *et al*., 2010), who ranked specimens according to their associated data:

Class I: taxonomic identification plus field collection data, notably date and location - accessioned into the main research collection.
Class II: taxonomic identification only - not accessioned but retained as a destructive research resource.
Class III: neither of the above - disposal.

Within the above system Class I eggs are potentially available for sampling using minimally destructive techniques, for example where the case for research is very strong and no other material is available. However, these techniques would be developed on Class II material, which is also used for any research involving more than minimal damage.

Physically sorting YMT's undocumented collection using this approach was outside the scope and resource of this project. Instead, the decision-tree that Russell, *et al*. (2010) used to assign specimens into different classes was used as a framework for interrogating the collection catalogue to help identify specimens of requested species for destructive sampling. This framework was extended for the regional museum setting, where Class II or III specimens may be considered of value due to display or learning potential or local links. Class II specimens with additional evidence of provenance, such as those within an original collector's cabinet, were considered of greater potential cultural or educational value than those without. These were ranked against each other, taking into account aesthetic value, condition and completeness. Effectively this meant that a series of original collector's cabinets or single specimens with handwritten labels but only Class II data was highlighted as of value, for example in revealing the story of egg collecting as a popular historic pastime. Class II specimens at the other end of this spectrum were prioritised for sampling for this research project, and might in future be amalgamated to a taxonomically-arranged unaccessioned destructive sampling collection. Class III specimens were not considered in depth as they were not useful to this research project.

In practice, answers to initial key questions greatly facilitated this 'bottom-up' approach to identifying specimens suitable for destructive analysis using the collection catalogue. The curator could identify the least data-rich specimens in worst condition (cracked, broken or affected by Byne's disease) for each species when considering which to sample from, and subsequently consider factors including rarity or cultural value. Above all, the small sample size required for this project opened up a larger portion of the collection for research.

Due to small sample size required, and curatorial recognition that being attached to this research increased the value of individual specimens, which also offered the potential for re-testing results, all specimens sampled were accessioned into the main collection for their scientific value, despite some being poor in data or condition.

Sampling

Sampling technique was refined using non-collection eggshell before taking samples from specimens in the collection, which because of their age could be delicate and brittle. Very fine scissors or dental tools were used to remove small amounts of shell from around the original collector's hole or from broken edges of damaged specimens. Care was taken to check that no collector data or marks which might be present near a blow-hole were compromised, and if in doubt sampling was not undertaken. In some specimens the blow-hole was covered over, which prevented sampling. All specimens sampled were photographed before and after.

Research Results

The researchers obtained material for 56 species of bird in 13 orders from YMT's historic collections, aiding development of a new analytical technique for rapid taxonomic identification of eggshell in the archaeological record by peptide mass fingerprinting (Stewart, *et al*., 2013).

Development of this tool will facilitate new insights into patterns of use of the eggs of non-domestic bird species by people in the past. Bird eggs have been a significant resource for people through time. They are highly nutritious as foodstuffs, have symbolic value in many cultures (for example of fertility or rebirth), and their various components have been used to make, for example, containers, jewellery or paint (Stewart, *et al*., 2014). However there have been large gaps in knowledge about use of

wild bird eggs, a potentially important interaction between many cultures and the ecosystems in which they lived, in part due to lack of a taxonomic identification tool (Stewart, *et al*., 2014).

Initial research by the team involved with this project, focusing on two sites in Anglo-Scandinavian York, has revealed both an apparent lack of exploitation of the eggs of wild birds, even though these were presumably readily available, and that relative prevalence of goose eggshell may become a useful indicator of status (Stewart, *et al*., 2014).

Whilst a recent study has urged caution in using museum eggshell for proteomics research because some proteins present in modern eggshell were not recovered from museum specimens (Portugal, *et al*., 2010), the success of our analysis, for which the full suite of eggshell proteins was not required, highlights that museum collections are an invaluable resource to this field.

Conclusions

Museums receive ever increasing numbers of requests for destructive analysis of specimens, often using novel technologies that possess limited track records. At the same time cuts in resourcing for natural sciences collections mean that museum staff have limited resources to process and interrogate these. Where technology is novel, there is also a risk that the outcomes may be limited.

This project highlights the value of early and open dialogue between curatorial staff and research scientists, which enables hard questions to be asked on the science: how many, how much, what will we learn? It also highlights the willingness of researchers to directly contribute to the cataloguing of collections if the curator is able to support this. Close working helped promote a shared understanding and led to a streamlined request that was for the most part approved.

The researchers' drive to invest time early on to refine analytical technique and establish the smallest amount of material required for robust results reduced the 'destructive' nature of the request and opened up more of the collection for testing, and this research to reduce required sample size is still on-going. One outcome of this research is a web-based software tool www.thermal-age.eu which attempts to estimate the level of molecular destruction in bone samples based upon the thermal history of the sample.

The value of retaining data-poor egg collections and / or specimens in poor condition is also highlighted (*cf* Russell *et al*., 2010). Ultimately this research will continue to generate stories of past human interactions with our natural world that would not be possible without museum collections. This is of value both in helping to engage audiences and in advocating the scientific value of natural sciences collections even where data or condition are poor. By working together we can help push the boundaries of scientific research on museum natural history collections whilst ensuring this precious resource is preserved for the future

Acknowledgements

The research within which this took place was funded by a Collaborative Doctoral Award (Grant ref: AH/I504958/1) between the AHRC and York Archaeological Trust, awarded to the University of York. The following people have helped at various stages in the conception and execution of this work: Emma Bernard, Douglas Russell (Natural History Museum); Charlotte Sabey-Corkindale (University of York); Jane Sidell (English Heritage); Jan Bolding Kristensen (Zoological Museum, University of Copenhagen); Pip Strang (Blue Tokay); Stuart Ogilvy (York Museums Trust). We also thank the anonymous expert reviewers for their comments and advice, which helped greatly improve this paper.

References

Buckley, M., *et al.* (2009). Species identification by analysis of bone collagen using matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry. *Rapid Communications in Mass Spectrometry*. **23**. pp.3843-3854.

Carter, J. (2000). The Conservation of Molluscan Collections. *The Biology Curator*. **18**. pp.17-20.

Carter, D. & Walker, A. K. (1999). Chapter 9. Policies and procedures, in Carter, D. J. & Walker, A. K. (eds.) *Care and conservation of natural history collections.* Oxford: Butterworth Heinemann.

Lightman, B. (2000). The story of nature: Victorian popularizers and scientific narrative. *Victorian Review,* 1-29.

Manson-Bahr, P. (1959). Recollections of some famous British ornithologists. *Ibis.* **101(1)**. pp.53-64.

Portugal, S.J., Cooper, H.J., Zampronio, C.G. Wallace, L.L. & Cassey, P. (2010). Can museum egg specimens be used for proteomic analyses? *Proteome Science*. **8**. pp.40-45.

Richter, K., *et el.* 2011. Fish'n chips: ZooMS peptide mass fingerprinting in a 96 wellplate format to identify fish bone fragments. *Journal of Archaeological Science*. **38** (7). pp.1502-1510.

Russell, D.G.D., *et al*.. (2010). Data-poor egg collections: cracking an important resource. In: Louette, M., Cael, G. and Tavernier, W. (Eds). 2010. Proceedings of the Sixth European Bird Curators Meeting. *Journal of Afrotropical Zoology,* Special Issue. pp.77- 82.

Stewart, J.R.M, *et al.* (2013). ZooMS: making eggshell visible in the archaeological record. *Journal of Archaeological Science*. **40**. pp.1797-1804.

Stewart, J.R.M., *et al* 2014) Walking on eggshells: a study of egg use in Anglo-Scandinavian York based on eggshell identification using ZooMS. *International Journal of Osteoarchaeology*. **24** (3). pp.247-255.

van Doorn, N., Hollund, H., Collins, M., 2011. A novel and non-destructive approach for ZooMS analysis: ammonium bicarbonate buffer extraction. *Archaeological and Anthropological Sciences.* **3** (3). pp.281-289.

APPENDIX 1.

YORK MUSEUMS TRUST
DESTRUCTIVE AND INVASIVE SAMPLING POLICY – NATURAL SCIENCES

1. YMT actively encourages non-destructive research on its natural science collections.

2. YMT will consider all requests for destructive and invasive research including all forms of sampling on a case-by-case basis and reserves the right to refuse permission to any request.

3. For all forms of research a request form including details of research justification, a researcher profile, a methodology statement and statement of dissemination will be required in advance prior to YMT's consideration.

4. YMT will only grant permission for destructive research once it has been convinced that the scientific justifications for the removal of samples from specimens are robust and worthwhile and the research question(s) cannot be addressed using non-destructive techniques.

5. Particular justification will be required for sampling from type or figured specimens; CITES specimens; extinct, endangered or historic specimens. Specimen uniqueness; preservation state (poorly preserved specimens will be targeted first); strength and feasibility of research; evidence of sufficient lab facilities, experience and proven track record of analytical technique will all contribute to YMT's decision on whether to approve a sampling request.

6. YMT will ensure that all activity conforms to legal and ethical constraints and to professional codes of practice, e.g. CITES legislation.

7. All sampling should be fully documented by the Curator so future researchers will know what has been taken. Documentation should link to any publication produced as a result of specimen sampling.

8. The specimen sampled should be fully recorded and measured by the Curator prior to sampling. Under some circumstances (for example if the specimen is intended for museum display or further metric work might be compromised) consideration should be given to producing a cast of parts that will be damaged or destroyed.

9. The Curator will advise researchers on how to house, label and document any residual samples if these are removed by the Researcher.

10. YMT will place all research on record in a publicly accessible research register. This will include project name, research objectives, date of research, outputs – publications and data holdings, research involving sampling, sample location and size, the sampling process and eventually the full records of the results of analysis.

11. YMT will retain any material removed but not destroyed during analysis in its collection.

12. YMT will devise a research framework in conjunction with recognised experts for its natural science collections.

All requests for access to research the natural science collections should be made to the Curator of Natural Science, York Museums Trust, Yorkshire Museum, Museum Gardens, YORK, Y01 7FR.

APPENDIX 2.

Destructive and invasive sampling request form developed for the Natural Sciences collections at York Museums Trust (YMT)

Based on templates shared by the Natural History Museum, London; York Bones Forum; Bristol Museum & Art Gallery and guidelines in Carter & Walker (1999).

YORK MUSEUMS TRUST
DESTRUCTIVE AND INVASIVE SAMPLING REQUEST FORM – NATURAL SCIENCES

YMT actively encourages research on its natural science collections. We also have a duty to care for our collections and preserve them for future generations.

Destructive or invasive research will be considered on a case by case basis according to YMT's sampling policy.

To enable us to process your request, please complete this form and return to:

Curator of Natural Science
Email:
Post: Yorkshire Museum, Museum Gardens, York, YO1 7FR

Processing of requests by the Curator and Collections Management team will take approximately 6 – 8 weeks. (This can change at the discretion of YMT.)

Informal initial enquiries to determine which specimens are available in the collections should be directed to the Curator of Natural Science.

PART 1: PERSONAL & INSTITUTIONAL DETAILS	
1.1 APPLICANT'S DETAILS	
Name	
Position	
Institutional address	
Email	
Telephone number	
1.2 DETAILS OF SUPERVISOR OR HOST Please note – requests from non-permanent staff (e.g. students or visiting researchers) must be accompanied by a letter of support from your supervisor or host, who accepts full responsibility to comply with the terms of agreement.	
Name	
Position	
Institutional address	
Email	
Telephone number	

1.3 DETAILS OF ANALYTICAL LAB TO BE USED	
Institutional address	
Contact name	
Email	
Telephone number	
PART 2: PROJECT DETAILS	
Project title	
Project outline: Please include aims, significance, outcomes and plans for dissemination.	
Sampling justification: Why is material from YMT's collections important to this research?	
Sampling methodology: How will the sample be taken; size of sample; location of sample on specimen; is the least destructive method possible being used? *Include photographs of sampling equipment & illustration of proposed sampling site.*	
Analysis: Brief outline of methodology; examples with references of previous studies evidencing competence of investigator and success of the particular technique used.	
Maximising sample use: Is the method of analysis destructive or non-destructive of the sample taken? If non-destructive, please indicate potential to share or re-use samples with future researchers.	
Duration of project (months):	
Date sample(s) required by:	
PART 3: SPECIMENS TO BE USED Please continue on a separate sheet if necessary.	
Taxon / taxa	
Number of specimens required	
Additional specifications (if appropriate): geographical region / country; field collection date(s); sex; storage time; preparation or preservation conditions.	
Accession numbers (if known)	

YMT USE ONLY	
Date received:	
Date acknowledged:	
Review by:	
Accession number:	
Specimen data:	
Specimen condition:	
Type / figured:	
CITES / legal constraints:	
Extinct / Endangered:	
Historic, cultural or educational value:	
APPROVED / NOT (indicate reasons why):	
Signature of curator:	
Loan number:	
Date(s) of sampling:	
Residual sample(s) returned to collections:	
Copies of images received:	
Publication received:	

TERMS AND CONDITIONS

1. Destructive and invasive sampling requests are approved on a case by case basis at the discretion of the Curator and Collections Management Team.

2. YMT reserves the right to refuse permission for any destructive and invasive sampling request.

3. Particular justification is required for sampling from type or figured specimens; CITES specimens; extinct, endangered or historic specimens.

4. Applicants must provide any additional information requested by YMT in relation to legislation, e.g. CITES, before an application is approved.

5. Applications from non-permanent staff (e.g. students or visiting researchers) must be supported in writing by a supervisor, host or head of laboratory, who also takes full responsibility for adhering to terms and conditions.

6. Any costs associated with sampling will be borne by the applicant or host institution.
Sampling and analysis are solely for the non-commercial academic research purposes outlined in this form.

7. Access to specimens will only be allowed under supervision of appropriate Museum staff.

8. If handling of material by the Researcher is approved by the Curator this must be undertaken in an appropriate manner. The Researcher will be required to wear relevant personal protective equipment to ensure good standards of care for themselves and the collection.

9. Specimen accession numbers must be detailed in any publications and attached to any data stored in the public domain.

10. YMT retains all rights to all material sampled from its specimens.

11. Residual samples must be returned to YMT within a maximum period of one year (longer periods must be agreed in advance).

12. Applicants must follow guidance from YMT staff for the housing, numbering and labelling of specimens once sampled.

13. If the whole specimen is destroyed during the process then the Researcher must inform YMT.

14. Two copies of all publications resulting from research and copies of any images taken by the Researcher must be provided to YMT.

15. Researchers must provide feedback to YMT if analysis is not successful, detailing reasons why.

16. YMT will place a record of all research in a publicly accessible research register.

17. Use of specimen images must be approved by YMT's image use request procedure. Enquiries should be directed to the Curator of Natural Science.

18. Loan of material for sampling must be approved by YMT's loan request procedure. Enquiries should be directed to the Curator of Natural Science. Researchers must not remove any material from the collections without express permission.

SIGNATURES
I have read, understood and agree to abide by the statements above:

Applicant's name / title	
Applicant's signature	
Supervisor / host / head of lab's name / title	
Supervisor / host / head of lab's signature	

A Natural Curiosity: Evolution in the display of natural history museums

Carolyn L. Carlins

8005 Broadlawn Drive, Pittsburgh,
Pennsylvania 15237, United States

email: carlinsc@carnegiemnh.org

Received: 26th Aug 2014
Accepted: 1st Dec 2014

Abstract

Natural history museums have the unique capacity to provide a forum for contemporary issues such as climate change, genomics, or natural disasters. These modern museums act as institutions from which new and important advances can emerge. Within this role, natural history is involved not only with a scientific narrative, but a social narrative as well.

Developing from cabinets of curiosity to what is recognizable today as the modern museum, collections of natural history have undergone significant developments. This article will briefly look at the driving forces behind these historical developments focusing on an aesthetic of curiosity and display. Using three London-based museums as a case study the article examines the evolution of specimen-rich displays within natural history spaces, particularly in regard to their historical context, characteristics, and purpose. Following the historical background and relevant findings from the case studies, the article will consider how natural history institutions may evolve in the future. Current developments within institutions of natural science indicate that despite various historical transformations and modifications within displays, the future of contemporary natural history museums exists in adopting and acknowledging the historical value of an aesthetic of curiosity while embracing innovative and engaging ways of reuniting natural science with a participatory public.

Keywords: Natural history museums; Displays; Collections; Curiosity; Participatory public; Museology

Introduction

As museums evolve, they inherit traditions of meaning from the past and form new ways of projecting meaning through new and updated displays. This museological heritage within museums such as those with natural history, zoology, or ethnography, tends to work within established parameters of classifications and frameworks. These frameworks are continually influenced not only by museological traditions, but also by historical paradigms of contemporary science (Pearce, 1992).

Early amalgamations of specimen-rich collections, now known as cabinets of curiosities, form the first collections for many museums. In such collections often little was known of the objects that made up these cabinets and an aesthetic of curious fascination was fueled by intrigue in what was unfamiliar (Mauries, 2002). Developing from historical cabinets of curiosity to what is recognizable as the modern museum, collections of natural history have undergone significant changes. Today, the combination of curiosity and the physical display of objects in museums still has potential to form the roots of exploration, encouraging the continued development of science and technology.

Carlins, C. L. 2015. A Natural Curiosity: evolution in the display of natural history museums. *Journal of Natural Science Collections.* **2.** pp. 13-21.

This article will address curiosity as a property within the context of informal education settings of natural history museums. As such, it will consider the role of curiosity throughout the historical evolution of displays in natural history museums. The aim of this article is to examine the evolution of the display of specimen-rich collections within natural history spaces, particularly focusing on their historical context, characteristics, and purpose. This will be accomplished through examining displayed collections of natural history museums and the consideration of museological theory as it relates to how museums have developed their institutional role.

A comparative approach was taken using natural history collections at three museums in London: the University College London (UCL) Grant Museum of Zoology and Comparative Anatomy, the Horniman Museum and Gardens, and the Natural History Museum, London (NHM). London museums were chosen due to accessibility of materials and as a control variable from which to asses the data. Additionally these museums have been chosen for their diversity in size as well as historical development. As these museums only represent a localized fraction of displayed natural history collections, worldwide examples will also be considered where relevant. It is important to consider how specimen-rich displays of natural history collections have evolved in the context of historical paradigms, particularly the relevance of an aesthetic of curiosity, scientific advancement, and museology. Despite various transformations within displays, the future of museums of natural science exists in adopting an aesthetic of curiosity while embracing innovative and engaging ways of reuniting natural science with an integrated and participatory public.

Curiouser and curiouser: cabinets of curiosities

Dating to 1599, illustrative catalogues of cabinets of curiosities are some of the earliest representations of displays (Mauries, 2002). Illustrations of crowded, overflowing cases depict numerous specimens of the natural world and artifacts of man as well as the social interaction integral to such collections (Mauries, 2002). As little was known of these objects at the time, unfamiliar pieces encouraged discussion and inspired a fascination stemming from human curiosity. While chaotic in appearance, materials were organized as they were thought to relate to one another. Early collections, although variably organized due to individual collecting preference, were often displayed in categories aimed to tangibly illustrate chains of being that existed within art and nature.

Within the early days of collection forming the activity was a recreational diversion for all levels of society where individuals set out to collect, define, and classify objects. The formalization of collections into displays transformed the activity of collecting from a pastime of the common man to a more specialized and often pedantic pursuit. After collecting specimens, individuals understood them by identifying (taxonomy), sorting (classification), and determining relationships (systematics) between specimens. This process formed the foundations of the modern biological sciences (Freedman, *et al.,* 2010). Organization of displays by individual preference was beginning to be replaced by utilizing scientific systems designed by figures such as Linnaeus and Buffon (Mauries, 2002). Linneaus organised organisms into hierarchies, placing like organisms closer together in the hierarchy. Likewise, Buffon's research served as precursor to the scientific work of Lamarck and Cuvier (Freedman, *et al.,* 2010). Emerging developments in scientific fields contributed to a more objective understanding of relationships within the natural world and the processes by which these relationships were determined. Consequently, scientific systems of the 18th and 19th centuries created more distinct differences between disciplines and promoted more specialized research, resulting in objects redisplayed to reflect this. Within natural history museums, the application of emerging scientific theories provided for a more didactic understanding of relationships between specimens. Thus, the purpose of scientific understanding to instruct the public began to overshadow the presence of the marvel and curiosity within collections (Mauries, 2002).

Eighteenth and nineteenth century

Like cabinets of curiosity, Victorian displays also favored crowded cabinets. The aim of such displays was often to showcase power and progress (Gould, 1994). Faith in progress was fueled by a continuously growing body of knowledge and the first true natural history museums established themselves as places for expanding knowledge (Henning, 2006). The Museum d'Histoire Naturalle and its Jardin Des Plantes, established in 1793, was organized as an institute of research and study for the natural sciences and enterprise in Parisian science became the world measure for naturalist study. In addition to fueling research and study, museums also functioned to disseminate of information. Figures such as British naturalists Richard Owen and Adam Sedgwick viewed museum spaces as places for applied science, which provided visual instruction about the natural world. (Yanni, 1999). Labels identifying objects and specimens provided a means of mass communication to the public and objects-based display opened up the world. The expansion of knowledge about the natural world and the branching of disciplines such as biology, chemistry, and geology resulted from scientific advances. William Flower, curator of the NHM in the nineteenth century, describes some of these scientific developments as being due to (Flower, 1898):

- Discovery of enormous numbers of forms of life and their varieties
- Increasing knowledge of the structure of organic bodies, through techniques such as microscopic examination, and dissection
- The study of the geographical distribution of living things
- Establishment of paleontology as a science
- Zoological classification

One notable hallmark of development in the natural sciences during this time is Charles Darwin's theory of natural selection as published in On the Origin of Species by Natural Selection in 1859. The concept of natural selection gave rise to many Victorian political debates concerning evolution and its bearing on social development. Due to their positioning, museums served as a perfect stage for these dialogues. Thomas Huxley, English biologist, actively participated in political debate, strongly advocating natural selection and evolution. Understanding the role of museums in both retaining and shaping social traditions and environment, Huxley and his allies ensured that "their followers were appointed to key positions in the new museums of ethnology and natural history" (Bennet, 2001). The Pitt Rivers Museum, which used a typological method to stuff objects into display, initially intended to communicate the progression of society through evolutionary sequences.

Prior to the division of the disciplined study of natural history subjects, there were no professional naturalists (Barber, 1980). However, in efforts to expand collections, leading to the sponsorship of scientific expeditions and field research, it quite quickly became recognized (Norris, 2012). Due to the rate at which museums were collecting, storage and documentation were overlooked, but to be able to effectively utilize, interpret, and communicate knowledge, detailed information about the objects was essential (Norris, 2012). These changes in the way science was conducted transformed naturalist study from something that was done by the public to something that was passed down and disseminated to the public by an occupational authority (Henning, 2006). Due to revisions in scientific knowledge, Victorians questioned how to present scientific displays; whether to display exhibits as completed bodies of facts or to show the process of scientific work, leading to concerns of engaging the public (Yanni, 1999).

Gradually, the notion of a museum's civic duty to educate contributed to the conflict of interest between science education and spectacle entertainment, also known as edutainment (Asma, 2001). For example, taxidermy in the eighteenth and nineteenth centuries served two primary purposes: aesthetic enjoyment and scientific scrutiny (Yanni, 1999). Diorama painters were trained in "illusionistic devices" for creating realism and depth (Henning, 2006). The American Natural History Museum, founded in 1868, used panoramas and dioramas portraying realistic natural scenes to engage visitors which transformed visitors to spectators. Due to the combination of both available techniques for display and public expectations for recreation, museums faced an increasing pressure to act in accordance with popular appeal, often at the expense of museums as research institutions (Henning, 2006). Both an educational approach to scientific knowledge and appealing to visitor expectations have influenced the displaying of natural history collections.

Of natural history and museology: modern context

Having developed out of cabinets of curiosities, museums inherit existing systems and nomenclature for developing their displays (Pearce, 1992). Collections used for scientific advancement utilize systems derived from the revision of scientific standards, so standards within the natural sciences such as taxonomy, systematics, and evolution have historically formed an inherent basis for the construction of natural history displays. A consequence of this is the historical collection may not be seen as relevant for contemporary taxonomy and systematics (Suarez and Tsutsui, 2004). Natural history museums today inherit historical difficulties such as:

- Whether to present scientific facts as a completed body of knowledge, or to show the process by which scientists work and
- The disparity between education and entertainment

The future of natural history displays in both exhibition and interpretation contend to fit in with a combination of new scientific knowledge and mutable visitor expectations (Frost, 2010). Simply displaying objects does not necessarily make possible an understanding of science or the natural world (Dorfman, 2012). Natural history exhibitions which go beyond the basic identification of traditional displays are more demonstrative of natural science concepts, driven by the organization of naturally occurring phenomena. However, displays which solely rely on explanation can fail to engage the public, disconnecting visitors from the physical subject matter of the natural world. Displays of a more thematic nature consider concepts surrounding the natural world and place primary importance in public education through narrative. Such displays have the potential to emphasize entertainment and often become out of date with scientific advancement, which inhibits their ability to educate and limits their potential to engage current information.

Museological considerations

Peter Vergo's *The New Museology* (1989), asserts museology as a distinctive discipline and defines the concept of the New Museology as a dissatisfaction with the 'old' museology, which he views as "too much about museum methods, and too little about the purposes of museums". The New Museology pays particular attention to the relationship of a museum to its social, economic, and political environment. The concern that Vergo wishes to address is the possibility of museums becoming "living fossils," unable to connect with contemporary audiences (1989). *The Intangible Roots of Our Tangible Heritage* (Norris, 2012) has similar concerns, but believes that in some ways, museological practice has stripped objects of their intangible aspects, such as an object's status as a curiosity. Removing an intangible aspect from an object has the potential

to decrease its perceived value and lessen its impact upon audience engagement. The aim in exploring the New Museology and its critiques within the context of a natural history setting is to consider the applicability and influence of developments as they interact with natural history institutions.

Results

The main objective in analyzing the three museums and their displays is to illustrate the evolution of displays through their context, characteristics, and purpose, paying particular attention to the role of curiosity as an aesthetic concept. This attention to curiosity's role intends to acknowledge the historical value of curiosity while illustrating it's continued relevance and suitability to participatory engagement and education.

The three museums used as case studies for this research are:

1. Grant Museum of Zoology and Comparative Anatomy UCL – small museum of natural history established within academia and developed through its purpose as a teaching collection and as a implement of public education.

2. Horniman Museum and Gardens - medium museum of natural history established as a private, individual collection and developed through its purpose to the public education and engagement.

3. Natural History Museum, London (NHM) - national museum of natural history established as a branch of the British Museum and developed through its involvement in scientific research, attention to public engagement, and understanding of global influence.

Grant Museum of Zoology and Comparative Anatomy UCL

University College London's Grant Museum of Zoology and Comparative Anatomy in Bloomsbury began as a teaching collection and was associated with labs, accessible for academic research and other educational purposes by UCL staff, namely anatomy and biology students (Fig. 1). The collection was first created by Robert Edmond Grant (1793-1874), a mentor to Charles Darwin, who left nearly 10,000 specimens to UCL at his death (Carnall & McEnroe, 2011).

The Grant Museum has gradually transformed from a teaching collection into a museum and has only recently moved into a new museum space facing many transitional issues such as content and display. During the move, the museum's Victorian display was noted for being an attractive and important aesthetic to maintain for the museum's public, the new museum space aims to preserve this aesthetic while improving the museum's contemporary relevance and ability for public education and engagement (Fig. 2).

To compensate for a lack of space, the Grant Museum crams it display cases with specimens as well as uses supplemental materials such as Factfile, and QRator, an iPad-based application.

Fig. 1. Image of the teaching collection from the Grant Museum of Zoology being used in a classroom in 1887.
(Image copyright UCL, The Grant Museum of Zoology)

Fig. 2. Image of the redisplay of the Grant Museum of Zoology in 2013. (Image copyright UCL, The Grant Museum of Zoology)

Horniman Museum and Gardens

While the Horniman Museum originates from a private collection, it was established as a publicly oriented museum since 1891 and has inherited a tradition of Victorian aesthetic in display. Although galleries have undergone minor renovations, evaluations reveal that although aesthetically engaging, the outdated displays present a disconnect between content and audience (Hatton, 2013). In July of 2006, the Natural History department of the Horniman Museum, in consultation with the Susi Fisher Group, conducted an evaluation of local audiences with the objective of informing a refurbishment of the gallery (Fisher, 2006). As a community based space, the Horniman Museum has acted as a mixture of both investing in the future and preserving nostalgia. The evaluation uncovered that the natural history gallery is perceived as the "heart of the old museum," making it symbolic of its history (Fisher, 2006). Horniman Museum visitors seem to desire a greater interaction with the displays, they are however, unimpressed with modern materials and methods of display. According to the evaluation, visitors wanted to "preserve the feel of nature itself," allowing the aesthetic of the display to feel in tune with nature, presenting guests with an inherent unity of purpose (Fisher, 2006). Consideration of refurbishment and the desire for innovation reveal a need for more engaging displays, but there are difficulties of keeping the historically established space while introducing innovative means of engagement. Throughout its history, the museum's primary purpose remains public education and engagement and the possibility of renovation presents exciting challenges for proponents of innovative redisplay.

Natural History Museum, London

Originating from the collection of Sir Hans Sloane, the collections of the Natural History Museum, London (NHM) began as a donation to the British government. These collections of natural history were first exhibited for the public in 1753 and were subsequently housed in the building of the British Museum in Bloomsbury circa 1820 (Yanni, 1999). While originally an establishment of scientific pursuit, the NHM has evolved to also consider a relationship to the public and to the role of display in public education. Throughout the development of the NHM, certain displays have undergone radical change while others have remained relatively untouched. The following sections provide examples of the museum's evolution in display including: opposition to the redisplay of traditional collections, the development of updated displays for popular education, and a modern display diverging from past conventions. Three examples of this evolution in display can be seen in the Mineral Gallery, the New Exhibition Scheme, and the Darwin Centre Cocoon. Each will briefly be discussed.

The mineral gallery of the NHM has changed very little since it was originally erected as working display (Figs. 3 and 4). The specimens are arranged systematically and cases were planned according to their relationship to other specimens within the galleries. While the exhibition has remained relatively the same since it's inception, it has not been maintained without controversy. During the 1990s, the Natural History Museum conducted visitor research on the mineral gallery, which resulted in the conclusion that it was seen as "dull and irrelevant" by a majority of visitors (Clarke, 1990). Making a decision to build a better exhibition, the NHM sent out a letter asking for support and explaining the rationale for the gallery's development and aims.

Fig. 3. NHM Mineral Gallery, original installation. (Courtesy of Natural History Museum, London)

Fig. 4. NHM Mineral Gallery, present (Courtesy of Natural History Museum, London)

Immediately after these letters were posted, the NHM received letters from all corners of the world opposing any change to the mineral gallery. These letters, coming from sources such as the Rijksmuseum, the Museum of Victoria, and the British Jeweler's Association, identified the hall as a “mecca” for curators, specialists, students, and collectors (Birch, 1990). The Dresden Museum of Mineralogy even stated that “to remove it means to remove one gemstone of the crown jewels in the Tower!” (Quelmalz, 1990). Unlike the UCL Grant Museum or the Horniman Museum, the NHM and its galleries hold international influence and are accountable to international scrutiny. Such opposition to changing the mineral gallery, not only speaks of the timelessness of historical display, but also asserts purposed and practical applications of the display to contemporary times.

Beginning in the 1970s the Natural History Museum put in motion the New Exhibition Scheme (NES), the largest and most complex undertaking in display and exhibition since the museum’s inception. The NES exhibitions followed a visitor focused approach, forming objectives for three levels of visitors: all visitors and children, adults and older children, and adults and older children with interest or previous knowledge. Through utilizing visitor information from these groups, teams from the NES aimed to develop exhibitions with appeal to a wide range of target audiences.

The most recently developed gallery of the NHM is the Darwin Centre Cocoon, opened in September of 2009 (NHM, 2009). The centre endeavors to present a realistic display of science by putting the process of science at the center of the exhibition and showing what is science rather than showcasing scientific objects. This approach exhibits scientific research conducted at the NHM.

Despite its emphasis on showing the science at the NHM, few specimens of natural history are on display within the Darwin Centre. While the exhibition encourages participation, it lacks a sense of curiosity due to its pedagogical approach. Visitor reactions to the Cocoon have been both positive and negative. Many visitors enjoy the interactivity provided by the narrative, however others feel disconnected from the museum and its collection (Cunnyngham, 2013).

Each of these museums have evolved out of original institutions with differing purposes. Although each have different backgrounds, they show similar developments in regard to their context and characteristics. As modern museums, each one strives to engage public curiosity and embrace innovation.

Discussion

Modern natural history museums are institutions with collections and resources to enable advancement and have the capacity to act as a forum for relevant issues such as climate change, genomics, or natural disasters.In this way, natural history become involved not only with science, but with society, creating access to public engagement and education.

This paper has focused on the display of specimen-rich collections, taking into account the relevance of an aesthetic of curiosity, scientific advancement, and museology in an effort to examine how displays of natural history have evolved. Developments within science and society inform transformations and modifications in the way objects are

displayed. Historically, the following factors influence change in museums of natural science: contemporary context of science and society, external audience expectation, administration and management.

Generally throughout natural history museums, traditional exhibits show diversity through vast specimen-rich displays without much interpretation, with the purpose of showcasing for curiosity rather than educating. Displays which aim to be more demonstrative are generated by the purposes of public responsibility; more thematic displays consider concepts surrounding the natural world. Although such display engages, it also places concern in expectations of the entertainment sector.

Science is not just a method of allaying uncertainties and ordering the world, but a means of furthering advancing technologies and unearthing new uncertainties to resolve. This realisation has generated discussion among science communities and changes dialogue within natural history museums. So by simply displaying objects and providing a didactic flow of information within exhibitions is not sufficient for some modern museums. Ian Brunswick, Exhibition and Events Manager at the Science Gallery in Dublin, believes that traditional collections and archives are not dead, but are changing to match their context. He states that "the ability of a science centre to be extremely modern and changing all the time and involve visitors heavily even in the production of what's going on, that's a new thing that I think we are going to see innovation within big museums, but especially in small science centers" (Science Friday, 2013). While small, newer spaces have an advantage as they do not have traditional histories to contend with, larger institutions often have the advantage of research and a well of resources. Promoting innovation in both established and new museums involves bringing what is historically behind the scenes into view for the public and to be successful, this innovation relies on an aesthetic of curiosity and a participatory means of display that attempts to involve the visitors.

What do hedgehogs eat? Space for curiosity

The Horniman Museum's evaluation of the North Hall, discovered that despite the need for updating natural science displays, the traditional aesthetic still provoked curiosity and thus engaged public learning (Hatton 2013). Visitors, particularly children, were able to come face to face with taxidermy displays, wonder "What do hedgehogs eat?" and examine the possibilities (Fisher, 2006).

Spaces like the Horniman's North Hall and the NHM's mineral gallery and the Grant Museum are examples of places which retain their value because of their timelessness in curiosity. Displays of endless variety can attract many students to study the beauty of the natural world. This impact of aesthetic is not only applicable to the natural sciences, but also to the social sciences. An example of this is the Pitt Rivers Museum which also retains Victorian ambience as a display aesthetic (Fig. 5). Thus in both the natural and social sciences, the aesthetic of curiosity acts as historical value influencing and engaging with the public.

The Grant Museum's cluttered displays is another example of a return to this aesthetic of curiosity or of a museum that never left it, but continues to be popular in modern society. The interpretation devices within the new museum space assist in engaging interaction, yet the aesthetic of the space has even greater impact in inspiring an attraction to its natural history collection. Such structuring of meaning through display also endows objects of natural heritage with an intrinsic association of value within the contemporary world.

Fig. 5. The wonderfully packed and busy displays at the Pitt Rivers Museum in Oxford. (Photo by author in 2013)

Within the 21st century there has been a revival of interest in curiosity which can be seen in the rehabilitation of the cabinet of curiosity as a mode of display (Bann, 2006). Stottop (2012) examines certain exhibitions which present innovations in natural history display. The exhibition *Terra Cognita* (2012), a permanent geological exhibition at the Ruhr Museum, Germany, displays a wealth of material in the cabinet of curiosity aesthetic, evoking beauty, fascination, and mystery in order to attract visitors (Stottop, 2012). The exhibition displays geologic specimens along with additional collaboration with artists, scientists, and art curators. The innovation of a cross-disciplinary display structured as curiosity allows these materials to be presented as invaluable pieces of natural heritage.

The return of a participatory display

Although the cabinet of curiosity approach is perceived as struggling, at least one of the traditional functions is being revitalised: interactive participation. This social factor of participation invites involvement allowing for direct exploratory learning. The NHM's Darwin Centre Cocoon, although different from the cabinet of curiosity aesthetic, is an example of exploring the process of science rather than its objects. Despite the intent for visitor inclusion in the process of science, the Cocoon, falls short in its implementation. Inclusion within exhibitions ideally leaves visitors feeling empowered and connected rather than alienated from the process. In recognition of this museums today are making these places of natural science into non-exclusive social spaces, integrating a relationship between the study of science, the public, and other disciplines.

Participatory exhibitions are also becoming more cross-disciplinary. A "bioart" exhibition at the Science Gallery in Dublin, called *Bloodwars* (2013), invites audience participation through the use of their own blood. This is exploring the relationship between art and living systems, is set up like a tournament and pits immune systems against each other to determine which immune system is stronger. While the Science Gallery does not support a traditional display, it invites curiosity through participation, encouraging dialogue between scientists, contestants, and spectators. The project takes an active interest in the science behind the installation and encourages scientists to answer public questions such as what they are doing and to what purpose. There is not much precedence for collaborative displays which encourage this type of intimate visitor participation and stimulate cross-disciplinary discussion. Following the installation, the museum invited the public to discuss with curators and geneticists what should be done about the bio-waste to dispose of it ethically. Such considerations generate new conversations within contemporary science. In regard to modern understandings of the purpose of natural science museums, the purpose is to generate curiosity, leaving visitors with questions to explore.

Participatory displays engage and challenge science in a new way, inviting the public to either accept or reject the result of the scientific method. In this way, participatory displays open up considerations for new dimensions of understanding. In traditional displays, which intertwine disciplines, there is an understanding of both uncertainty (in the sense of curiosity) and participation (in the sense of interaction) in regard to the ability of materials of natural science to serve multiple purposes (Asma 2001). Examples today suggest that science and natural history institutions are working toward a more integrated relationship and changing the role of museums in regard to public endeavor.

Limitations and future research

The museums chosen for research were chosen for their specimen-rich displays and to demonstrate differences and similarities between natural history displays looking at historical context, characteristics, and purpose. However, all three museums are London-based and thus only represent a localised fraction of natural history collections, geographically limiting the results. In researching these museums, further limitations arose from the difficulty of determining the original ideas behind changing and modifying displays with poor documentation. Historical documentation did show that changes in museum displays occurred due to the influence of factors such as: contemporary context of science and society, external audience expectation, and the powers of administration and management.

As this research was constructed from a curatorial perspective rather than a visitor-based perspective, visitor evaluation and feedback were mostly excluded, with the exception of reference to one evaluation. Due to the participatory direction of natural history museums, future research should consider understanding the visitor's perspective. Another consideration is further research on an exhibition based perspective discussing how the realities of constructing display in a natural history setting reflect the theories explored in this article. In addition, while other types of museums were considered within the discussion section of this paper, research was only conducted on museums with historical, specimen-rich collections. Further research focused on the development of recently established museums and their displays would open up consideration for more modern structures within contemporary paradigms.

Conclusion

Natural history museums are intrinsically involved with not only scientific, but social narratives and have the unique capacity to act as a forum for contemporary issues within these contexts. Accordingly, scientific advances have the ability to emerge from these institutions. In order to allow for advances within institutional bounds, museums must ensure the availability of their information, collections, and resources. As stated throughout this paper the focus of the research is on the display of

specimen-rich collections, accounting for the relevance of an aesthetic of curiosity, scientific advancement, and museology. Despite various transformations within displays, the future of museums of natural science exists in adopting an aesthetic of curiosity while embracing innovative and engaging ways of reuniting natural science with an integrated and participatory public.

Historical context, particularly in regard to paradigms of scientific advancement and social change, is continually reflected in displayed material and what these displays convey to the public. Consciousness of historical context and consideration of museology assists in understanding the exchange of influence between museums and their environments. Both enable museums to develop visitor engagement and education concerning both contemporary issues and institutional research. The evolution of displays of natural history have shown recent developments That understand the link between the value of the traditional aesthetic of curiosity and involving visitors within display. Thus, the traditional concept of the natural history museum is not dead, but rather evolving along with its natural curiosity. Promoting innovation in both established and new museums involves bringing what is historically behind the scenes into view for the public. To be successful, this innovation relies on maintaining an aesthetic of curiosity and stimulating innovative, participatory displays.

Acknowledgements

I would like to express a fond thank you the editors of this journal and to all those who contributed to the support of this article. I extend special gratitude to the staffs of the Grant Museum of Zoology and Comparative Anatomy, particularly Mark Carnall and Emma-Louise Nicholls; the Horniman Museum and Gardens, particularly Paolo Viscardi and Joann Hatton; and the Natural History Museum, particularly Daisy Cunnynghame, who all kindly gave me guidance and access to essential research materials.

References

Bann, S. 2006. The Return to Curiosity: Shifting Paradigms in Contemporary Museum Display. In, McCellan, A. *Art and its Publics: Museum Studies at the Millennium.* Oxford: Blackwell Publishing.

Birch, B. 1990. Letter About the Mineral Gallery at the Natural History Museum from Museum of Victoria; Melbourne, Australia, [letter] Natural History Museum Library and Archives, DF700/4/1/8, London: Natural History Museum Library and Archives.

Carnall, M. & McEnroe, N. 2011. Relocating the Grant Museum of Zoology and Comparative Anatomy. *Collections: A Journal for Museum and Archive Professionals.* **7 (2)**. pp.123-144.

Clarke, G. C. S., 1990. Letter About the Mineral Gallery at the Natural History Museum, [letter] Natural History Museum Library and Archives, DF700/4/1/8, London: Natural History Museum Library and Archives.

Cunnyngham, D. 2013. The Nature of Display in Natural History Museums. Interview by Carolyn Carlins [oral interview]. Natural History Museum Reading Room 21 August.

Dorfman, E. 2012. *Intangible Natural Heritage: New Perspectives on Natural Objects.* New York: Routledge

Filippoupoliti, A. 2010. "...Collected in one view" Some Early Concerns with Staging Science in the 1876 London Exhibition of the Special Loan Collection of Scientific Apparatus." in, Filippoupoliti, A. *Science Exhibitions: Communication and Evaluation*, Edinburgh: Museums. MuseumsEtc.

Fisher, S. 2006. What do people want from a natural history gallery? *NATSCA News.* July **(9).** pp.15-21.

Flower, W., H. 1898. Essays on museums and other subjects connected to natural history, London: Macmillan.

Freedman, J., *et al.* (2010) "Taxing Taxonomy, Scary Systematics and Confusing Classification: Interactive Activities to Make Scientific Jargon More Accessible." in, Filippoupoliti, A., *Science Exhibitions: Communication and Evaluation.* Edinburgh: Museums, MuseumsEtc.

Frost, W. (2010) Jurassic Park and Visitor Interpretation for Museum Dinosaur Exhibits. In, Filippoupoliti, A., Science Exhibions: Communication and Evaluation, Edinburgh: Museums. MuseumsEtc, pp. 150-184.

Gould, S. J. 1994. Cabinet museums revisited: jam-packed Victorian displays still contain up to date messages, *Natural History.* (January) 16.

Hatton, J. 2013. The Nature of Display in Natural History Museums, Interview by Carolyn Carlins [oral interview]. Horniman Museum and Gardens 9 August.

Henning, M. 2006. Museums, Media and Cultural Theory. Open University Press, Maidenhead, Berkshire, England: McGraw-Hill Education.

Heyer, W.R. (2008) Can Long Established Scientific Societies Survive the Digital Age? *Washington Academy of Sciences*. **94 (2).** pp.17-33.

Horniman Museum and Gardens 1893. Third Annual Report of the Horniman Museum, [report] Horniman Museum and Gardens Forest Hill, London S.E.: Horniman Museum and Gardens

Mauries, P. 2002. *Cabinets of Curiosities.* Thames and Hudson Ltd. London.

Natural History Museum, 2009. Darwin Centre: The Grand Opening of Your Mind, [poster] Natural History Museum Library and Archives, DF514/1/1/10/50, London: Natural History Museum Library and Archives.

New Exhibition Scheme. 1970-2003. Planning and Scheduling in the New Exhibition Scheme: Introduction [manuscript] Natural History Museum 8 the Sound of Stones. In, Dorfman, E. *Intangible Natural Heritage: New Perspectives on Natural Objects.* New York: Routledge.

Suarez, A., V. & Tsutsui, N, D. 2004. The Value of Museum Collections for Research and Society. *Biosc-ence.* **54 (1).** pp.66-74.

Trustees Standing Committee. 1871-1880. Extracts from Minutes of the Trustees Standing Committee: At a committee 8 February 1879, [manuscript] Natural History Museum Library and Archives, DF902, London: Natural History Museum Library and Archives.

Trustees Standing Committee. 1871-1880. Extracts from Minutes of the Trustees Standing Committee: At a committee 23 June 1879, [manuscript] Natural History Museum Library and Archives, DF902, London: Natural History Museum Library and Archives.

Vergo, P. 1989. *The New Museology.* London: Reaktion Books Ltd.

Viscardi, P. 2013. The Nature of Display in Natural History Museums, Interview by Carolyn Carlins [oral interview]. Study Collections Centre, Horniman Museum and Gardens 9 July.

Yanni, C. 1999. *Nature's Museums: Victorian Science and the Architecture of Display.* London: The Althon Press.

Zubrowski, B. 1982. An Aesthetic Approach to the Teaching of Science. *Journal of Research in Science Teaching.* **19 (5).** pp.411-416.

Does Micro-CT scanning damage DNA in museum specimens?

Andie C Hall,[1] Emma Sherlock[2]

& Dan Sykes[1]

[1]Core Research Laboratories, The Natural History Museum, Cromwell Road, London SW75BD

[2]Life sciences, The Natural History Museum, Cromwell Road, London SW75BD

Corresponding author: a.hall@nhm.ac.uk

Received: 18th Oct 2014
Accepted: 29th Oct 2014

Abstract

X-ray micro-computed tomography and DNA sequencing are useful and increasingly common tools in taxonomy and collections research. Whilst the benefits of each method are continually evaluated and debated individually, how the methods impact each other requires more attention. We compared DNA fragment length and the barcode sequence CO1 in samples throughout a CT-scanning protocol, for a range of X-ray exposures and energies. We found no evidence of DNA damage, but advise caution when using precious or archival material, highlighting the need for further investigations and considering potential areas for research.

Keywords: Micro-computed tomography; X-ray microtomography; DNA fragmentation; PCR; Sanger sequencing; Barcoding; *Lumbricus terrestris*; Oligochaeta

Introduction

The taxonomist's tool kit is ever expanding with new technologies, posing new challenges to curators and institutions charged with safe-guarding collections. Whilst most concerns focus on how these new technologies affect the morphology and physical integrity of the specimen - little attention has been paid to how these new methods impact upon one another.

Current calls for a more comprehensive and integrated approach to species identification - including images, scans and genetic analyses (Deans, *et al.,* 2011; Butcher, *et al*., 2012; Wheeler, *et al*., 2012; Edmunds, *et al*., 2013; Faulwetter, *et al*., 2013b; 2014, Riedel, *et al*., 2013b; Stoev, *et al.,* 2013; Faulwetter, *et al*., 2014), highlight the need for this fundamental question to be answered - how best to use specimens, integrating these new technologies, while safeguarding collections for the future? In this study, we look at just one aspect of this issue - does X-ray micro-computed tomography (micro-CT) affect the integrity of DNA within a preserved specimen?

DNA sequence data is now routinely used for taxonomic studies (Cook, *et al.,* 2010, Riedel, *et al.,* 2013b) and has had a huge impact on our view of relationships within the animal kingdom (Giribet, 2010). They are regularly cited as a key to solving the taxonomic impediment (Rougerie, *et al*., 2009; Riedel, *et al.,* 2013b) not least because "DNA barcoding" creates a framework for describing large numbers of taxa in a relatively short time - so called "Turbo-taxonomy" (Monaghan, *et al*., 2005; Rougerie, *et al*., 2009; Butcher, *et al*., 2012, Riedel *et al*., 2013a) as well as revealing otherwise cryptic or ambiguous taxa (Hebert, *et al.,* 2002, Perez-losada, *et al.,* 2009; James, *et al*., 2010). Sequence data are useful at every level of taxonomy - from individuals (Sharma, *et al*., 2011) to high level, deep divergences (Dunn, *et al*., 2008, Edgecombe, *et al.,* 2011). Edgecombe, *et al.,* (2011) describe it as "the most ground shaking innovation in modern phylogenetics".

Hall, A. C., Sherlock, E., & Sykes, D. 2015. Does Micro CT scanning damage DNA in museum specimens? *Journal of Natural Science Collections*. **2.** pp. 22-28.

Micro-CT uses X-rays to generate 2D images of a specimen. As the specimen is rotated within the X-ray beam, hundreds or even thousands of images are collected at different rotational angles. Cross-sections are computed from these "shadowgrams" to build up a 3D model of the specimen. From this model, the specimen can be examined from any angle, sliced along any plane, or digitally dissected through a process of segmentation that can be used to reveal complex internal anatomy in ways that are exceedingly demanding through other techniques (for example serial sectioning, dissection or skeletonisation). Since the process is carried out with the specimen intact, usually still within its storage box or jar, it is often described as non-destructive.

Its widespread adoption (Giribet, 2010) has been credited with causing a renaissance in morphology (Budd & Olson, 2007). Since the technique allows detailed studies of the internal anatomy of specimens, without damaging morphology (when compared to traditional histological techniques or dissections), there have been calls for large-scale scanning of whole museum collections (Faulwetter, *et al.,*2013b).

However, X-rays (and other types of ionising radiation) cause damage to DNA such as Double Strand Breaks (DSBs) Single Strand Breaks (SSBs), abasic sites, intra-strand crosslinks, inter-strand crosslinks, oxidation and the deamination of cytosine to uracil (Brotherton, *et al.,* 2007, Dexheimer, 2013). Such damage may cause a blocking lesion (preventing polymerase from acting on the strand and halting PCR) or a miscoding lesion, where the DNA is sequenced incorrectly (Heyn, *et al.,* 2010). Obviously, DSBs fragment the DNA into smaller pieces which can affect the suitability of DNA for both Sanger and Next-generation sequencing.

Micro-CT is ideal for imaging hard, calcified structures such as bone, but the low X-ray absorbtion of low density non-mineralised tissues means that samples must be stained if soft tissues are to be imaged. Table 1 shows commonly used contrast stains for soft tissues and typical protocols. Iodine is a simple, effective and non-toxic stain which provides good contrast for alcohol preserved specimens (Metscher, 2009; Faulwetter, *et al.,* 2013a). However, Iodine stains have been shown to inhibit PCR (Marin, *et al.,* 2000; Auinger, *et al.,* 2008) and the staining and rinsing process (soaking the specimen in stain solution at room temperature for hours/days, then washing post-scan) may leave DNA vulnerable to decay by hydrolysis.

Previous studies have used PCR success to assess DNA damage in specimens analysed by X-ray radiography (Gotherstrom, *et al.,* 1995) and micro-CT scanning (Faulwetter, *et al*., 2013a). PCR may be inhibited by iodine stain, blocking lesions, or severe fragmentation, but miscoding lesions would not be detected by a simple "Will it amplify?" approach. PCR is an extremely powerful technique which can amplify pieces of DNA from just a single strand. All that is needed is one strand of intact, undamaged DNA from the area of interest. Any damage to other copies, or the rest of the genome, will go unnoticed. Also, PCR products may be generated from damaged DNA by "Jumping PCR" (Pääbo, *et al*., 1990). The result is chimeric fragments made up of a number of different sequences joined together. Such fragments would only be discovered by sequencing. Viable DNA and expected sequences have been obtained from micro-CT scanned gastropods (Suzanne Williams, *pers comm.* 2014) and polychaetes (Faulwetter, *et al*., 2014). However, optimal exposures and energies were used to obtain clear images. It has been the case that museum specimens on loan have

Stain	Stock solution	Staining procedure
PTA	1% (w/v) phosphotungstic acid in water	Mix 30 ml 1% PTA solution + 70 ml absolute ethanol to make 0.3% PTA in 70% ethanol. Keeps indefinitely. Take samples to 70% ethanol. Stain overnight or longer. Change to 70% ethanol. Staining is stable for months. Scan samples in 70% – 100% ethanol
IKI	1% iodine metal (I2) + 2% potassium iodide (KI) in water	Dilute to 10% in water just before use. Rinse samples in water. Stain overnight. Wash in water. Can be scanned in water or dehydrated to alcohol.
I2E, I2M	1% iodine metal (I2) dissolved in 100% ethanol (I2E) or methanol (I2M)	Use at full concentration or dilute in absolute alcohol. Take samples to 100% alcohol. Stain overnight or longer. Wash in alcohol. Stain does not need to be completely washed out before scanning.
Osmium tetroxide	standard EM post-fixation	Same as routine EM processing. Osmium-stained samples can be scanned in resin blocks, with some loss of contrast.

Table 1. Contrast stain formulations and protocols, from Metscher, 2009.

been Micro-CT scanned at unnecessarily high energies and exposures, leading to DNA damage (Isabelle De Groote, *pers comm.* 2014). For this reason, we wanted to test a greater range of scanning protocols.

It should be noted that the 2 extremes of our chosen dose range are not expected to produce optimal images. The purpose of this study is to seek evidence for damage to DNA as a result of micro-CT scanning and to establish guidelines for collections staff and not to provide methodologies for effective micro-CT analyses. The lowest voltage / lowest exposure scan was chosen as image quality may need to be compromised in order to safeguard collections. The highest voltage / highest exposure scan was chosen to maximise potential damage to DNA.

Hada & Sutherland (2006) demonstrated that X-rays induced DSBs, reducing the average length of DNA strands. However they irradiated DNA in solution and found that damage correlated strongly with microenvironment, suggesting that the interior of a cell would provide a radiation quenching microenvironment thus protecting the DNA within tissues. Paredes, *et al*., (2012) used a bioanalyser to analyse fragment length of DNA extracted from bird skins, comparing before and after micro-CT fragmentation profiles. They found no difference in profile and thus no evidence of DSBs. However, the DNA was highly fragmented to start with, probably as a result of preservation techniques. They are clear that their results might not be applicable to other tissue types or organisms such as invertebrates.

Evidence of DNA damage in calcified structures such as teeth and bone has been found following X -ray radiography (Gotherstrom, *et al.,*1995, and Knapp, 2013) and following Micro-CT (Grieshaber, *et al.,* 2008) but so far as is known, there is no evidence of damage in soft tissues.

As discussed, micro-CT of soft tissues may require staining, which could itself cause damage to DNA. The possible effects of Iodine stain (Marin *et al.,* 2000; Auinger, 2008) and chemical drying (Austin & Dillon, 1997) on PCR have been assessed but, as far as is known, no study has yet considered the effects of each stage of staining and scanning. Here, we test for miscoding lesions and DSBs in fresh samples before processing, after staining, after scanning, and after stain removal (washing).

We chose to focus on the mitochondrial gene Cytochrome Oxidase 1 (CO1) due to the availability of robust protocols and comparable sequences on Genbank. As a "DNA barcode" (Hebert, *et al*., 2003) it is also the focus of much of the museum's requests for molecular analyses.

Earthworm identification normally requires detailed dissections and the use of micro-CT has been proposed as a potential non-destructive method (Fernàndez, *et al.,* 2014). We therefore anticipate an increasing number of requests to scan such material. Difficulty of identification (particularly for novel or cryptic species) and controversies over taxonomic grouping, means there is also demand for molecular analyses on this group (Huang, *et al.* 2007, Perez-Losada, *et al.* 2009, Rougerie, *et al*. 2009, James, *et al.* 2010, James & Davidson, 2012). We chose the lobworm, or nightcrawler, *Lumbricus terrestris* Linnaeus (1758) for this trial due to its availability and ease of storage. The specimens in the collections at the Natural History Museum vary widely in their tissue type, age and preservation. To control for variability in quality of material (and to safeguard collections against unnecessary risk) this initial study used fresh material, euthanised on the first day of testing. All individuals were the same species, of the same age and from the same source.

Materials and Methods

14 adult clitellate *L. terrestris* purchased from Worms Direct UK were starved overnight on wet tissue paper. They were anaesthetised in 30% ethanol for a few minutes, then 100% ethanol for 10mins. Worms were washed in 2 changes of 100% ethanol before being cut into 3 body segments - head, clitellum and approx. 3cm of the body, from the tail-end. Body parts were stored in 100% ethanol at 4°C overnight and labelled 1-14, depending on which worm they came from.

Worms were treated as three separate pieces in case of variation between body segments caused by different tissue types or thickness, and between worms. Therefore each scan was assigned one head, one clitellum and one tail, but from different worms.

A tissue sample consisting of a single cross-section, one body segment in width and weighing approximately 15mg was taken from each body part at the following stages:

A) Post -euthanising
B) Post - staining
C) Post - scanning
D) Post – washing

All samples were stored in 100% ethanol at -20°C until DNA extraction.

X-ray micro-computed tomography

Each body part was stained by soaking in a solution of 1g crystalline iodine (VWR) in 100ml of 95% ethanol, for 4 hours at room temperature before being transferred to absolute ethanol. Body parts were secured for scanning by sliding them into plastic tubes embedded in Oasis floral foam (Oasis floral products) in a plastic beaker. The tubes were sealed with cling film to prevent evaporation, and the body parts were scanned in air rather than ethanol to provide greater contrast than would be possible between soft tissue and ethanol.

X-ray micro-CT scans were performed using a Nikon Metrology HMX ST 225 (Nikon metrology,

Tring, UK) micro-CT scanner. All scans were carried out at 150µA with a molybdenum target and 3,142 projections were taken over a 360° rotation with no frame averaging.

Samples were CT scanned at exposures of 354ms, 708ms and 2000ms, with accelerating voltages of 50, 100, 160 and 220 kV. A no-scan control sample was treated the same as 2000ms samples, but was left on the bench instead of being placed in the scanner. These parameters were chosen to represent a wide range of potential doses, from a 'safe' scan of short scan duration and low voltage (20 minutes for a low exposure of 354ms at 50 kV), to a maximum exposure scan of a long scan time and high voltage (two hours for a high exposure of 2000ms at 220 kV).

After scanning, body parts were transferred to 100% ethanol. Destaining should ideally be carried out immediately after scanning, but due to time constraints, specimens were stored at -20°C for three weeks. They were washed by soaking in several changes of 70% ethanol at room temperature, until the solution no longer changed colour. This process took over a week and samples were stored in the fridge over the weekend. They were then transferred through a series of washes, (80%, 90% and 100% ethanol) for long term storage at -20°C.

Data treatment

The 3D volumes were reconstructed using CT Pro (Nikon metrology, Tring, UK) using a modified Feldkamp back-projection algorithm (Feldkamp, et al., 1984). The 3D data sets were then rendered using VG Studio Max (Volume Graphics, Heidelberg, Germany) to produce visualisations (based on the density of the material) and to analyse the quality of the scans and produce virtual cross sections of samples.

DNA analyses

DNA extractions were performed using a Qiagen DNeasy blood and tissue kit, as per manufacturer's protocol "Purification of Total DNA from Animal Tissues" with the following modifications:

1. Tissues were washed in 500µl 1xTE twice to remove gut contents and residual ethanol.
2. Samples were digested for 2 hours at 56°C. Many samples were difficult to lyse and required grinding with a micropestle, or addition of another 20µl proteinase K. Samples were not vortexed post lysis.

DNA was eluted in 100µl of buffer AE and concentration estimated using a Qubit 2.0 fluorometer (Invitrogen).

Strand length analysis

DNA was diluted to give a final concentration of 10-100ng and analysed using an Agilent 2200 TapeStation with Genomic DNA ScreenTape, as per manufacturer's instructions.

PCR

A 658bp fragment of the CO1 gene was amplified using the barcoding primers (after Folmer, *et al.,*1994):

LCO1490 (5'-GGTCAACAAATCATAAAGATATTGG-3')
HCO2198 (5'-TAAACTTCAGGGTGACCAAAAAATCA-3')

Each reaction consisted of 0.4mM total dNTPs, 2mM $MgCl_2$, 1.5u Bio-Taq DNA polymerase (Bioline), 0.04µM each primer and 1x reaction buffer (67mM Tris-HCL, 16mM $(NH_4)2SO_4$, 10mM KCl). Cycling conditions were: initial denaturation 94°C for 1 min followed by 30 cycles of 94°C for 30s, 45°C for 30s and 72°C for 15s, with a final elongation of 3mins at 72°C.

Sanger Sequencing

PCR product from post-euthanising and post-washing samples (A and D) were cleaned using Millipore multiscreen PCR 96 filter plates, as per manufacturer's instructions and sequenced bi-directionally using BigDye terminator reaction mix v3.1, in a 3730xl DNA analyser (Applied Biosystems). Sequences were aligned using Geneious pro version 5.4.6 (Biomatters). PCR clean-up and sequencing were carried out by the NHM sequencing facility.

Results

Micro-CT

The low kV/ short exposure scans produced data that wasn't ideal because the signal to noise ratio in the scan was poor, meaning that some features could not be identified in the data. The short exposure time also produced lower contrast between features of different densities (Fig 1, left). The high kV /long exposure scans demonstrated better signal to noise ratio in the scan, making features more easily discernible. However, some features are still lost, in this case, due to the high energy of the X-rays saturating the detector panel in regions of low density material since the X-ray beam was only lightly attenuated (Fig, right). The best quality scans were obtained using 100 kV and 708ms exposure times. These conditions gave a long enough exposure to produce good contrast, but without saturating the detector panel in regions of low density. These scans had the most clearly discernible features (Fig 1, middle).

PCR and sequencing

DNA extraction got progressively easier with treatment (A was the hardest and D the easiest) with many samples requiring physical disruption by grinding and vortex mixing or extra proteinase K during lysis. Some samples (particularly treatment A) were very difficult to lyse. All samples were successfully amplified by PCR. There were no sequence differences between before and after samples for any treatment .There was considerable sequence variation between individuals, but no other factor affected the DNA sequence, or the DNA amplifiability. There was therefore no evidence of miscoding or blocking lesions.

Fragment length analysis

If staining, scanning and washing all caused DSBs, the electropherogram peaks produced by the Tapestation would be expected to spread out and move down the x axis from treatment A through to D

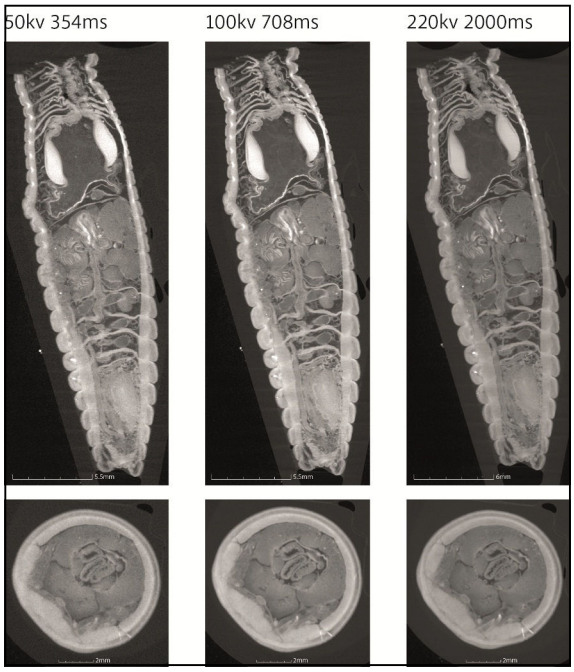


Fig. 1. CT scans of the anterior section, cut just before the clitellum, of specimen one *Lumbricus terrestris*. Top: longitudinal sections, Bottom: cross sections. Left images: Scanned at 50kv, 354ms, Middle images: Scanned at 100kv, 708ms, Right images: Scanned at 220kv, 2000ms. NB these images are from repeat scans taken after sampling, for illustrative purposes.

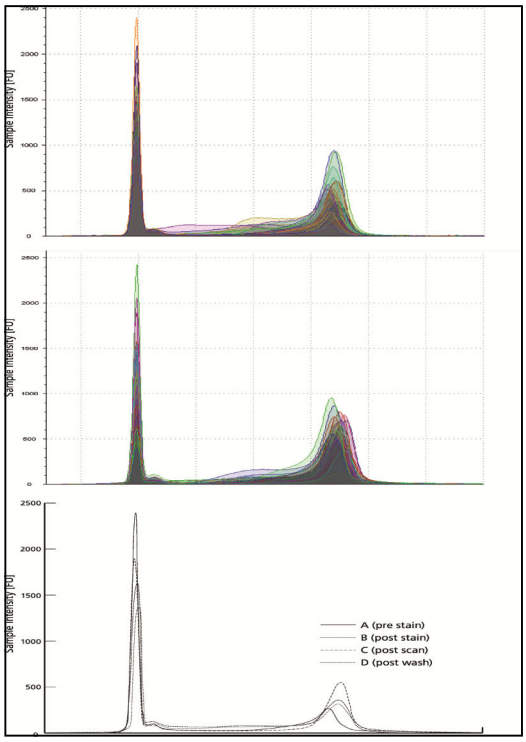


Fig. 2. Example of overlaid electropherograms showing DNA fragment sizes (x axis) against frequency (sample intensity in fluorescence units). The first peak is an internal marker at 35 bases. Comparison of Pre-stain/Group A (Top image) and Post wash/Group D (Middle image) shows variation within groups, but not between groups. The bottom image shows electropherograms for the Clitellum of scan 220kv 2000ms. There was little change in strand length distribution from pre-scan (Group A) through to post-wash (Group D).

(because the broken DNA would be shorter). Overlaying the electropherograms revealed no such pattern. Variation was marked across the samples but was no worse for treatment D than A. I.e. there is no appreciable difference between the electropherograms of stained, scanned and washed samples and those of fresh samples (Fig 2).

Comparison of modal strand length (as reported by the Tapestation) in Group A (Pre-stain) against D (Post wash) using a paired Ttest showed a significant *increase* in fragment size (T= 4.75 P= 1.3x10-5). T tests for each scan showed a significant increase for Scans160kv/354ms (T=3.86 P=0.03), 20kv/708ms (T=10.03 P=0.004), 220kv/2000ms (T=3.61 P=0.03) and the no scan control (T=4.62 P=0.002) (Fig 3).

If the treatments tested induced DSBs, a decrease in modal strand length would be expected. This does not happen when comparing all body parts together for each treatment (Figure 2 top and middle, Fig 3 top) nor for any of the body parts when considered individually. Fig 2 bottom and Fig 3 bottom show an example. In fact, samples in treatment D were significantly longer than those in treatment A. Therefore there is no evidence of DSBs induced by any treatment.

Discussion

Micro-CT did not affect modal length of DNA fragments in any of the samples, therefore we find no evidence of X-ray induced DSBs. Fragment length was highly variable across all samples, but generally increased with processing. The DNA extraction method is column based and therefore causes shearing as DNA passes through the filter. A number of methods were trialled (Gentra Puregene and QiaAmp mini kits from Qiagen, Free-it and CA solution from Clent Biosciences and DNAzol from Life Technologies), but none was consistently better than any other. Thus the DNeasy kit was chosen for its ubiquity in molecular biology. We noted that tissue lysis (the first step in DNA extraction) became progressively easier after staining, then scanning, then washing, with some samples requiring extra proteinase K and grinding or vortex mixing to breakdown tissues. Faulwetter, *et al.,* (2013a) found that Iodine inhibited lysis in polychaetes (Katerina Vasileiadou *pers comm.* 2014) and although our washed samples were the easiest to lyse, our unstained samples were the most problematic. Ethanol toughens Oligochaete tissues. We suggest that the process of staining and washing softened the tissues, allowing easier lysis and less physical disruption which would break the DNA. It is therefore likely that DNA shearing was primarily caused by the DNA extraction process rather than

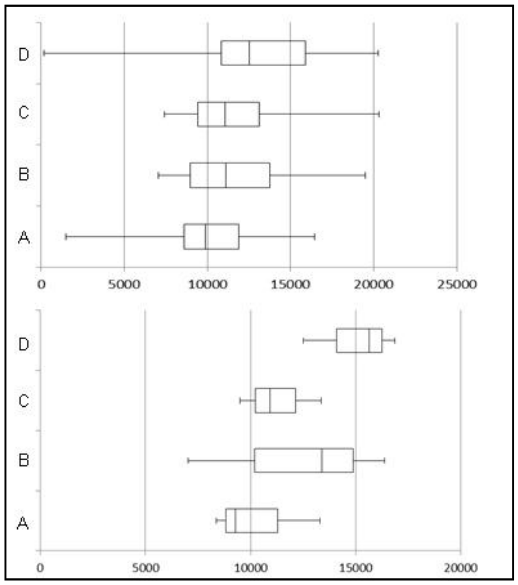


Fig. 3. Box and whisker plot showing the distribution of modal strand length (x axis) for Top: all samples. Bottom: Scan 220kv, 2000ms. The modal strand length increased with treatment, rather than decreased which would be expected if staining, scanning or washing induced DSBs.

anything else, as results were inconsistent with any other variable.

Stains may also be tissue specific (Faulwetter, *et al*. 2013b; Sykes, *et al.* 2013) meaning that, over time, one museum specimen may be subject to a number of different stains and repeated scanning. Since processing the samples seemed to affect the tissues, it may be argued that repeated staining, scanning and washing of the same specimen could cause degradation, particularly of soft tissues. Metscher (2009) stated that "each new type of sample must be tested with different fixations and stains to find the best treatment for the imaging required". We cannot say what effect other stains would have, or how iodine would affect other tissues or organisms. Indeed, even protocols for the same stain vary widely; our oligochaetes were soaked in Iodine for 4 hours, Metscher (2009) suggests overnight, whilst Faulwetter, *et al.,* (2013b; 2014) soaked polychaetes for up to 5 days. Optimisation of protocols before working on collections materials (to minimise manipulation of specimens i.e. staining and exposure) would be prudent.

There was no variation in amplifiability across the samples, all DNA extractions gave a distinct band of the expected size, and the DNA sequences remained unchanged. We therefore detected no miscoding or blocking lesions. However, we only looked at one mitochondrial gene and as already noted, PCR is an extremely powerful technique which can amplify pieces of DNA from just a single strand. It is possible that DNA was damaged, but in insufficient amounts to be detected by our method. Also, lesions induced by ionising radiation tend to be clustered (Nikjoo, *et al.,*1997; Sutherland, *et al*.,2000; Nikjoo, *et al.,* 2001, Semenko & Stewart, 2004; Hada & Sutherland 2006) rather than spread, so whilst no damage was seen in the CO1 gene, we cannot rule out damage to the rest of the genome.

We found no evidence of DSBs, blocking lesions or miscoding lesions induced by micro-CT. However, due to the issues outlined above, other techniques should be employed to verify our results before micro-CT can be declared safe for precious material. A number of techniques have been used to measure DNA damage, such as HPLC (Pääbo, *et al.,*1989), Single primer extension SPEX (Brotherton, *et al.,* 2007) NGS/sequencing by synthesis (Gilbert, *et al*., 2007), Polymerase Extension Profiling PEP (Heyn, *et al*., 2010) and DNA profiling (Knapp, 2013). These techniques are more expensive, time consuming and/or less robust than the methods employed here, so were not included in this initial analysis.

Conclusions

We found no evidence of DNA damage derived from micro-CT scanning or associated staining. Whilst (as far as is known) all studies have recovered viable DNA from scanned specimens, it is not clear whether the DNA has been damaged in other ways, due to the limitations of the detection methods used. Collections managers must consider future uses for specimens: Whilst Micro-CT scanning does not appear to hinder current DNA analyses, future technologies may be hampered by as-yet undetected damage. Comparing the entire genome of a specimen both before and after scanning using NGS is suggested as a next step in considering these difficult points.

Also, due to the vast range of methods, organisms, tissue types and variability in quality and quantity of DNA (fresh vs archival or ancient specimens for example) it is impossible to predict the effects of micro-CT on museum specimens in general. We therefore echo the comments of Paredes, *et al.,* (2012) that "Users seeking curatorial permission to scan rare specimens ...should carry out a [pilot] study on less valuable material."

Acknowledgments

All work was carried out at, and financed by, the NHM. We would like to thank the NHM sequencing facility for carrying out all PCR clean-ups and Sanger sequencing. We thank Sam James for advice on earthworm barcodes, Aiden Emery for advice on archival DNA damage and analyses and Kevin Hopkins for assisting with the tape station. We thank Amy Donnison for assisting with image processing and presentation, Colin Hall for annotating and resizing our images and Professor C. Csuzdi for his advice on earthworm anatomy. Thanks to the anonymous reviewers and their invaluable comments.

References

Austin, A., D., & Dillon, N. 1997. Extraction and PCR of DNA from parasitoid wasps that have been chemically dried *Australian Journal of Entomology* **36**: pp.241–244.

Auinger, B., M., *et al.* 2008. Improved methodology for identification of Protists and microalgae from plankton samples preserved in Lugol's iodine solution: combining microscopic analysis with Single-cell PCR, *Applied Environmental Microbio logy.* **74(8).** pp.2505.

Brotherton, P., *et al.* 2007. Novel high resolution characterisation of ancient DNA reveals C>U-type base m odification events as the sole cause of post mortem miscoding lesions, *Nucleic acids research*. **35(17).** pp.5717-5728.

Budd, G. E., & Olsson, L. 2007. Editorial: a renaissance for evolutionary morphology, *Acta Zoologica.* **88.**1.

Butcher, B. A., *et al.* 2012. A turbo-taxonomic study of Thai Aleiodes (Aleiodes) and Aleiodes (Arcaleiodes) (Hymenoptera: Braconidae: Rogadinae) based largely on COI barcoded specimens, with rapid descriptions of 179 new species, *Zoo taxa.* **3457.** pp.1–232.

Cook L. G., *et al.* 2010. Need morphology always be required for new species descriptions? *Invertebrate Systematics.* **24.** pp.322–326.

Deans, A. R., *et al.* 2011. Time to change how we describe biodiversity, *Trends in Ecology & Evolution.* **27.** pp.78–84.

Dexheimer, T. 2013. Chapter 2. DNA Repair Pathways and Mechanisms, in Mathews, L.A. *et al.* (eds.) *DNA Repair of Cancer Stem Cells.* 19 Springer Science+Business Media Dordrecht.

Dunn, C. W., *et al.* 2008. Broad phylogenomic sampling improves resolution of the animal tree of life, *Nature*. **452.** pp.745-749.

Edgecombe, G. D., *et al.* 2011. Higher-level metazoan relationships: recent progress and remaining questions, *Organisms Diversity & Evolution*. **11.** pp.151–172.

Edmunds, S. C., *et al.* 2013. Biodiversity research in the "big data" era: GigaScience and Pensoft work together to publish the most data-rich species description*, GigaScience*. **2.** p.14

Faulwetter, S., *et al.* 2013a. Contrast enhancing tech niques for the application of micro-CT in marine biodiversity studies, *Microscopy and Analysis.* **27 (2).** S4-S7 (EU)

Faulwetter, S., *et al.* 2013b. Micro-computed tomography: Introducing new dimensions to taxonomy*, ZooKeys* **263.** pp.1–45.

Faulwetter, S., *et al.* 2014. Can micro-CT become an essential tool for the 21st century taxonomist? An evaluation using marine polychaetes, *Microscopy and analysis.* **11.** S9-S12.

Feldkamp, L. A., *et al.* 1984. Practical cone-beam algorithm, *Journal of the Optical Society of America.* **1 (6).** pp.612-619

Fernández, R., *et al.* 2014 Sine systemate chaos? A versatile tool for earthworm taxonomy: non-destructive imaging of freshly fixed and museum specimens using micro-computed tomography, *PLoS ONE*. **9(5)** e96617.

Folmer, O., *et al.* 1994 DNA primers for amplification of mitochondrial cytochrome c oxidase unit I from diverse metazoan invertebrates*, Molecular Marine Biology and Biotechnology.* **3.** pp.294–299.

Giribet, G. 2010. A new dimension in combining data? The use of morphology and phylogenomic data in metazoan systematics. *Acta Zoologica.* **91.** pp.11–19.

Gotherstrom, A,. *et al.* 1995. X-raying ancient bone: a destructive method in connection with DNA analysis. *Laborativ Arkeologi.* **8.** pp.26–28.

Grieshaber, B. M., *et al.* 2008. A pilot study into the effects of X-ray and computed tomography expo sure on the amplification of DNA from bone. *Jour nal of Archaeological Science.* **35:3.** pp681–687.

Hada, M. & Sutherland, B. M. 2006. Spectrum of Com plex DNA Damages Depends on the Incident Radiation, *Radiation Research*. **165(2).** pp.223-230.

Hebert, P. D. N., *et al.* 2003. Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London B.* **270.** pp.313-321.

Heyn, P., *et al.* 2010. Road blocks on paleogenomes—polymerase extension profiling reveals the frequency of blocking lesions in ancient DNA. *Nucleic Acids Research*. **38(16)** e161

Huang, J., *et al.* 2007. Identifying earthworms through DNA barcodes. *Pedobiologia.* **51.** pp.301—309.

James, S. W., *et al.* 2010. DNA Barcoding Reveals Cryp tic Diversity in Lumbricus terrestris L., 1758 (Clitellata): Resurrection of L. herculeus (Savigny, 1826). *Plos One.* **5(12)** e15629.

James, S. W., & Davidson, S. K. 2012. Molecular phylogeny of earthworms (Annelida : Crassiclitellata) based on 28S, 18S and 16S gene sequences. *Invertebrate Systematics.* **26.** pp.213–229

Knapp, E. L. 2013. An Assessment of the Effect of X-ray Radiation on DNA Marker Profiles Obtained from Human Teeth, Master's Thesis, University of Ten nessee. http://trace.tennessee.edu/utk_gradthes/2444

Marin, I., *et al.* 2000. Preparation of DNA Suitable for PCR Amplification from Fresh or Fixed Single Dinoflagellate Cells. *BioTechniques.* **30.** pp.88-93

Metscher, B. D. 2009. MicroCT for comparative morpho logy: simple staining methods allow high-contrast 3D imaging of diverse non-mineralized animal tissues. *BMC Physiology*. **9.** p11.

Monaghan, M., *et al.* 2005. DNA-based species delineation in tropical beetles using mitochondrial and nuclear markers. *Philosophical Transactions of the Royal Society of London B* **360(1462).** pp.1925-1933.

Pääbo, S*., et al.* 1990. DNA damage promotes jumping between templates during enzymatic amplification. *Journal of Biological Chemistry.* **265.** pp.4718–4721.

Paredes, U. M., *et al.* 2012. Micro-CT X-rays do not fragment DNA in preserved bird skins. *Journal of Zoological Systematics and Evolutionary Research.* **50.** pp.247–250.

Perez-losada, M., *et al.,* 2009. Phylogenetic assessment o f the earthworm Aporrectodea caliginosa species complex (Oligochaeta: Lumbricidae) based on mitochondrial and nuclear DNA sequences *Mole cular Phylogenetics and Evolution.* **52.** pp.293–302.

Riedel, A., *et al.* 2013a. One hundred and one new species of Trigonopterus weevils from New Gui nea. *ZooKeys.* **280.** pp.1–150.

Riedel, A., *et al.* 2013b. Integrative taxonomy on the fast track - towards more sustainability in biodiversity research. *Frontiers in Zoology.* **10**. p15.

Rougerie, R., *et al.* 2009. DNA barcodes for soil animal taxonomy. *Pesquisa Agropecuaria Brasileira.* **44 (8).** pp.789-801

Sharma, A., *et al.* 2011 Analysis of Genetic Diversity in Earthworms using DNA Markers. *Zoological Science.* **28(1).** pp.25-31.

Stoev, P., *et al.* 2013. The centipede genus Eupolybothrus Verhoeff, 1907 (Chilopoda: Lithobiomorpha: Lithobiidae) in North Africa, a cybertaxonomic revision, with a key to all species in the genus and the first use of DNA barcoding for the group. *ZooKeys.* **50**. pp.29-77.

Sykes, D., *et al.* 2013. 3D Virtual Histology of Poly chaetes Using Micro-CT. *Microscopy and Microanalysis.* **19(S2).** pp.644-645p

Wheeler, Q. D., *et al.* 2012.. Mapping the biosphere: ex ploring species to understand the origin, organization and sustainability of biodiversity. *Systematics and Biodiversity.* **10(1).** pp.1-20.

Cleaning a dolphin skull and mandible to enable assessment of an unusual mid-nineteenth century scrimshaw

Nigel R. Larkin[1], Janet West[2] & Laura Porro[3]

[1]Cambridge University Museum of Zoology, Downing St, Cambridge, CB2 3EJ, UK.

[2]Scott Polar Research Institute, Lensfield Road, Cambridge, CB2 1ER, UK.

[3]Structure and Motion Laboratory, Department of Comparative Biomedical Sciences, Royal Veterinary College, University of London, Hatfield, AL9 7TA, UK.

Corresponding author: nrlarkin@easynet.co.uk

Received: 16th Sept 2014
Accepted: 16th Oct 2014

Abstract

A very dirty skull and mandible of a rough-toothed dolphin with two scrimshaw images engraved on its surfaces needed to be cleaned so that the artwork could be properly assessed. A suitable and effective method of cleaning the bones was required which would not damage the artwork and, in particular, would not adversely affect the pigment used in the scrimshaw. No method could be found in the published literature so an existing gentle technique for cleaning osteological museum specimens was tried. After tests on the specimen provided good results, a conservation grade non-ionic detergent was used: Synperonic A7 alcohol ethoxylate. Small areas of the bone surface were gently swabbed with very small amounts of a dilute solution of the detergent in distilled water, then swabbed again just with distilled water and dried immediately with paper towels. The cleaned scrimshaw proved interesting. It shows a sailor by a ship's wheel and a three-masted ship under sail, rigged with a 'main spencer' and was probably engraved between 1830 and 1860. Pictorial scrimshaw left on a complete bone such as a skull or a mandible is unusual.

Keywords: Dolphin; Skull; Mandible; Scrimshaw; Cleaning; Conservation

Introduction

Amongst the ca. 4,000,000 natural history specimens in the Cambridge University Museum of Zoology is an unusual example of the art of 'scrimshaw'. Two images, a sailor and a ship, were engraved on the skull and associated mandible of a 'rough-toothed dolphin' (*Steno bredanensis* [ex. *rostratus* Cuvier] (Lesson, 1828)). Museum records show that the specimen was donated by a Mr Peachey in 1872, giving a latest date for the collection of the specimen and for the artwork. As there was relatively little commercial interest in scrimshaw until around the mid 20th century, it is likely that the skull was presented as a specimen for taxonomic purposes, with the engraving considered irrelevant.

Now considered an important maritime folk art, 'scrimshaw' is the name given to the wide variety of incised, carved and variously decorated items mainly made during the 19th century and primarily by those engaged in the whaling industry (West & Credland, 1995). The name is also used for the creative activity itself. The most common scrimshaw materials were the marine mammal products derived from the various whaling industries. These were typically baleen (known as 'whalebone'), part of the keratinous feeding apparatus in the mouths of whales of the small sub-genus *Mysticeti* (baleen whales); jawbone ('panbone') of any of the great whales; and the large teeth of the sperm whale (*Physeter catodon* (Linnaeus, 1758)).

Larkin, N. R., West, J., & Porro, L. 2015. Cleaning a dolphin skull and mandible to enable assessment of an unusual mid-nineteenth century scrimshaw. *Journal of Natural Science Collections.* **2.** pp. 29-34.

This is the only great whale in the large sub-genus of *Odontoceti* (toothed whales) which includes porpoises and dolphins. Their teeth are a form of ivory, as are the tusks of walrus and narwhal and scrimshaw could be worked on these materials as well as other products such as wood, horn and tortoiseshell.

For pictorial scrimshaw, images would be scribed into the surface of the baleen, bone or ivory with a sharp point or blade. To enhance the contrast on the bone or ivory a pigment, usually black, was worked into the grooves. 'Lamp-black' (soot and oil) was often used, or for black or brown baleen a mixture of chalk and oil (West & Credland, 1995). The bone of cetacean mandibles is unusual, being particularly dense and evenly textured so the jaws of larger species were sawn, turned or shaped and polished to make a wide variety of scrimshaw, from walking sticks to baskets, toys, games and jewellery. Although some small cetaceans such as porpoises, dolphins and pilot whales were caught by whalers from time to time primarily for their meat, known as 'sea beef', scrimshaw on whole cetacean skulls is rare. Even decorated mandibles, or those separated into two at the symphysis, are less common than scrimshawed sperm whale teeth. They are generally considered bizarre rather than beautiful and scrimshanders chose less challenging materials if possible.

This particular scrimshawed dolphin skull and mandible is unusual because the bones have not been separated and the artwork has not been cut away from the specimen but has been left '*in situ*'. Scrimshaw artwork is normally presented on blank panels of bone or on single teeth, devoid of the rest of their osteological context. This specimen has had nothing removed and the pieces of artwork remain in their original context on the skull and associated mandible. This is rare and of historical interest.

The specimen has two clear examples of scrimshaw decoration. One is located on the occipital bone of the posterodorsal aspect of the cranium, showing the starboard side of a three-masted, full-rigged ship under sail (Fig 1, bottom left). The other is towards the rear of the right mandible and depicts a sailor holding a ship's wheel (Fig 1, bottom right). Although both images have black pigment in their incised lines the former initially appeared less well defined and more crudely executed. However, it was difficult to examine the specimen as it was covered in dust, dirt and sooty particulates (Figs 1, 2, 3 & 4). In addition, there was evidence of an earlier attempt to clean the rear of the skull, apparently with water, but rather than removing the dirt this had just moved it around and made more of a mess, further obscuring the artwork (Fig 1, top left & bottom left).

Cleaning the specimen

It was clear that both the skull and mandible needed to be cleaned to preserve the specimen, and so that the scrimshaw could be studied and assessed. Therefore an appropriate conservation treatment was required that would remove the dirt without harming the bone surfaces or wash away the unidentified pigment used for the scrimshaw.

No conservation techniques for cleaning scrimshaw could be found in the published literature. However, from past experience and in discussion with colleagues it was judged that the most effective way of cleaning the bone to remove the unsightly deposits gently without mobilising the pigment (and thereby spreading it and/or removing it) would be to swab small areas of bone with cotton wool lightly dipped in an aqueous solution of Synperonic A7, followed by swabbing with cotton wool dipped in distilled water to remove the Synperonic A7 (cotton wool pads, balls or buds could be used) and gently dry-

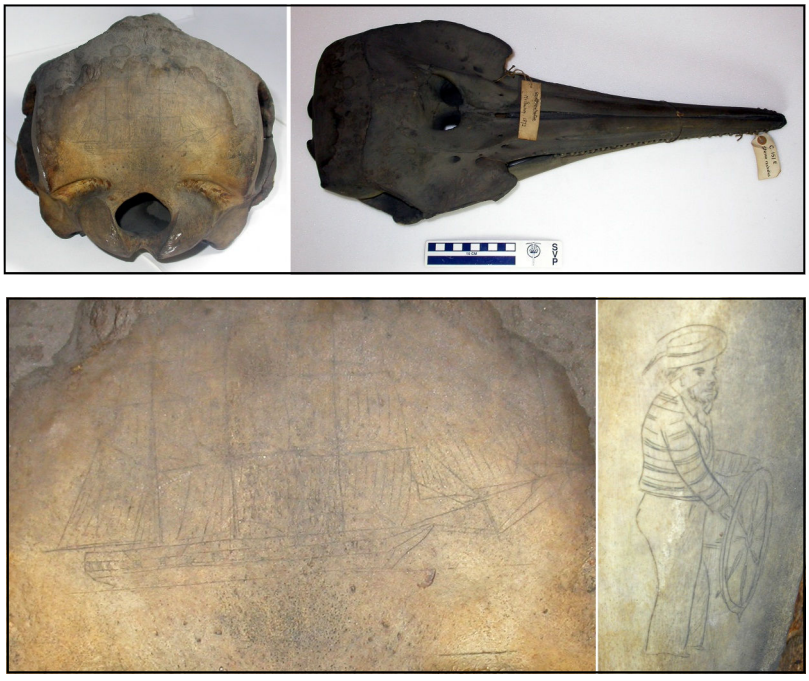


Fig. 1. Top Left: Posterior view of the skull, showing how an attempt made in the past to partially clean the rear of the skull with water was unsuccessful.

Top Right: Dorsal view of the articulated skull and mandible, showing the condition of the specimen was before cleaning (scale in cms).

Bottom Left: The scrimshaw artwork depicting the starboard side of a fully rigged ship under sail, on the occipital bone of the posterodorsal aspect of the cranium, before cleaning

Bottom Right: The scrimshaw artwork depicting a sailor at the wheel of a ship, on the proximal end of the right mandible, before cleaning (this photo has been rotated through 90˚so that the figure is the right way up).

Fig. 2. The test area of the scrimshaw that was cleaned first (scale in cms).

Fig. 3. Halfway through cleaning the rear of the skull (scale in cms).

ing the area immediately with a paper towel. Synperonic A7 is an alcohol ethoxylate that has recently replaced 'Synperonic N', a mild non-ionic detergent that had been widely used by conservators in museums for decades to clean osteological specimens and other material. It can be used as a detergent, wetting agent, non-ionic surfactant, and an emulsifying and dispersing agent (McCutcheons, 2003; Hackney, *et al.*, 1990).

Before this method was tried on the artwork, a small test area on an undecorated part of the mandible was cleaned. As this was found to be successful a small area of scrimshaw was very gently cleaned with this method (Fig 2). The artwork remained completely unchanged and there was no colour on the cotton wool swab other than from the surrounding dirt, therefore the pigment had not been mobilised and the technique was deemed to be a success. The rest of the specimen was subsequently gently cleaned with this method, patting each area of the bone gently with a paper towel to dry it immediately after cleaning so that the small amounts of water used had little chance to soak into the bone. This was to reduce the chances of the bone warping and/or splitting due to the sudden wetting and to reduce the chance of the pigment being affected. Fig 3 shows the process half way through cleaning the rear of the skull. The specimen is now noticeably cleaner and the scrimshaw artwork is clearer and more easily and effectively studied (Figs 4, 5, and 6).

Discussion

The dolphin

The conservation status, habits and distribution of the rough-toothed dolphin are poorly understood as this species inhabits deeper waters (>1km depth) off the continental shelves of the world. However, its range seems to be broad with reports from the Atlantic, Pacific and Indian oceans, typically in warm temperate, subtropical or tropical waters (West, *et al.*, 2011). Therefore little can be said about the specimen's likely geographical origins. However, once the specimen had been thoroughly cleaned the artwork could be assessed much more easily and accurately, enabling a relatively reliable date to be put to the artwork and the specimen itself, as well as facilitating other observations.

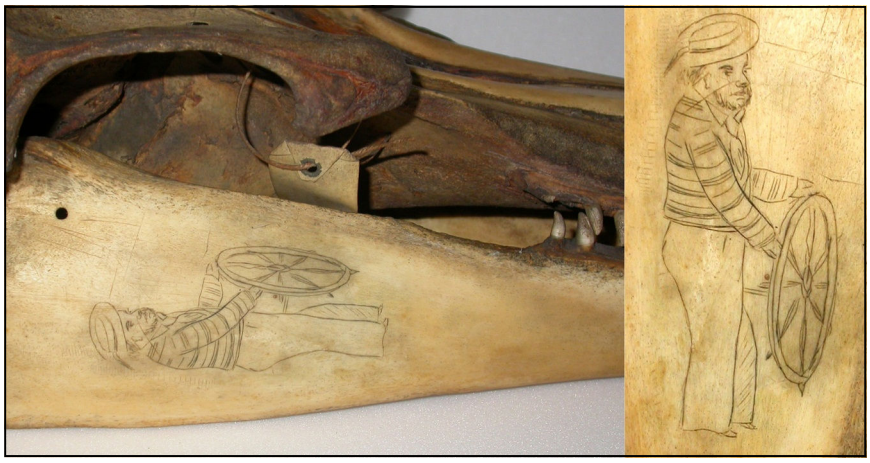


Fig. 4. The artwork depicting a sailor at the wheel of a ship, on the proximal end of the right mandible, after cleaning (far right, detail turned through 90˚ so the figure is the right way up).

Fig. 5. The occipital bone of the posterodorsal aspect of the cranium, after cleaning. The scrimshaw with the starboard profile of the ship clearly shows the main spencer, which is the (fore- and aft) gaff sail on the main lower mast. It is narrower than the similar spanker/driver on the mizzen (aftermost) mast.

The scrimshawed ship

On the occipital bone at the rear of the skull is the starboard profile (broadside) view of a three-masted ship under sail. The hull has either a single gun deck, or, more likely, a line of painted false 'gun ports', often called 'Nelson chequer', but there is nothing else to suggest a naval ship. She is flush-decked (with no raised quarterdeck, poop or forecastle) and her deck has little or no sheer (an upward curve towards the bow and stern). Her bow has a curved forward extension and the stern appears to have galleries or windows on its quarters.

All three masts carry 'square' sails on yards. The fore- and main-masts each have, from bottom to top, a 'main' or 'course', a 'top-sail', a 'top-gallant' and a 'royal' sail. The mizzen (the aftermost mast, usually without a 'course') has no royal. The top-sails (second row up) are 'single', i.e. they have not been divided horizontally into upper and lower sections for ease of management. This became common on some merchant ships by the 1850s or 1860s, but not on whaling ships or naval vessels as both carried relatively large crews. She also carries the usual 'fore-and-aft' sails: i.e. in line with the keel. These are the headsails and the spanker/driver on the mizzenmast. An additional interesting feature is the main spencer: a gaff trysail resembling the spanker/driver at the stern, used as a staysail and set abaft (behind) the main mast. Like the other fore-and-aft sails, spencers could utilise wind unavailable to square sails. They were a transitional form between the older trapezoid staysails and the long-lasting triangular form, still found on large square-rigged vessels. Most of those now afloat are relatively modern sail-training ships. Spencers were advocated for British merchant vessels in 1824 (MacGregor, 1984: 28) and they appear on both British and American whaleships scrimshawed by Frederick Myrick of Nantucket ca.1829 (West, 2000: pls 1; 4-7; 9-10). Although they remained in common use until ca. the 1860s, they are rarely found on scrimshaw. The lines down the sails, not always shown, indicate the canvas cloths which were stitched together to make the sails. However, the uneven nature of the medium (discussed below) would preclude much fine detail.

The scrimshawed figure

The sailor on the posterior of the right mandible is a stocky man with disproportionately short arms and legs, tiny feet and hands and a large head. His clothes are characteristic of a seafarer. He is wearing a canvas or straw hat (not tarred as it is light coloured), with a rather narrow brim and the crown encircled by a band with loose ends. Although the man's shape is vague, his features are well-defined. His shirt/jersey has both broad and narrow stripes and a scarf or kerchief is knotted at his collar. His light coloured trousers are fairly wide. The short vertical line from the waist probably indicates the right edge of a fall-front or flap opening with buttons on either side, the usual trouser fastening for many decades. He has shortish hair and an extensive, narrow, well-trimmed beard which, with the side burns (side whiskers), extends almost from ear to ear. This is possibly the best indication of a date for the image as nothing about his clothing is distinctive. Such whiskers are common on pictures of British sailors between ca. 1830 and the 1860s, though later some men also wore moustaches (Dickens 1957: pls. 18 & 19 & 1977: 18-20; Winton 1977: 54; 57; 66; 84; 120). Although obviously a helmsman, the disembodied ship's wheel would be very small for the vessel portrayed on the rear of the skull.

Whilst it is impossible to date most scrimshaw accurately, features of both images suggest a date between ca. 1830 and 1860.

Craftsmanship

Both ivory and bone are slightly plastic and distort when cut or scratched. Illumination of the surfaces with oblique light and magnification can show the tiny ridges and hollows made in the material by tools. Even minute grooves cast shadows and raised areas which have become polished by subsequent wear have reflective edges (West, 1989). Before engraving, scrimshaw materials were smoothed and polished. The simple hand tools and abrasive materials of times past produce quite different surface marks from the more efficient modern power tools and graded abrasives. Such surface characteristics can help to establish age and

Fig. 6. The articulated skull and mandible, after cleaning, with the artwork depicting a sailor at the wheel of a ship towards the rear of the right mandible.

authenticity. The small irregularities produced can also reveal the tools used to 'engrave' pictorial scrimshaw and, sometimes more importantly, how they were used. The usual tool was a fine blade and/or a point, not a professional graver/engraving tool. Their penetration of the material is different: a blade usually undercuts the medium and raises a small flange whereas a point shatters the edges of a groove to varying extent. Experienced scrimshaw artists developed a characteristic style which can, with practice, be recognisable. This has occasionally enabled the work of some individual artists, whether anonymous or not, to be identified.

Visible in several places on the surface of this specimen, especially on the mandible, are areas of short parallel lines one millimetre or so apart, made by the ridges of a coarse file or rasp. There are also the traces of scrapers, fairly heavy metal blades which are held at approximately 90° to the surface and drawn across it under pressure. This removes smaller irregular surface features. Scraper blades soon develop a characteristic profile of minute ridges and hollows which can be recognised on different parts of a surface on which they were used. Traces from rasps, coarse files and scrapers are characteristic of old scrimshaw.

The response of the two worked areas to smoothing is different. The outer surface of the mandible is relatively flat and as cetacean mandibles are composed mainly of dense bone, its newly exposed surface has remained smooth. The sailor is engraved with a blade, held at an acute angle to the surface at least in places, as a few of the edges of the cuts are still raised above the surface. However, the bone appears to have been harder than expected (or the knife blunt) as many of the lines, though extensive, are shallow with tiny raised edges. The deepest lines, e.g. those used to outline the legs and arms, appear double-cut i.e. two cuts converging to remove a small 'V' of bone. His striped shirt is shown mainly by shallower cuts.

In contrast, the attempt to smooth the outer surface of the occipital bone has exposed a layer traversed by many pores and holes in a range of sizes. This layer, known as diploe, is a spongy bone layer between the outer and inner compact bone layers of the skull which houses a network of nerves and blood vessels (Adrian Friday, personal communication). In an attempt to smooth the surface, the scrimshaw artist inadvertently made the area more difficult to engrave. However, he has correspondingly adapted his technique by holding the blade almost vertically to make relatively deep cuts and sometimes double cuts, thus resulting in the lines of the image being as smooth as possible. Had he used slanting blade cuts (the most common method) to engrave the ship, the remains of the sectioned pores would have distorted the outline of the image even more. His lines are remarkably straight, as if a guide had been used, a device which would have been very useful for scrimshawing sailing vessels but which seems not to have been common.

It was very rare for scrimshaw artists to have had any form of training, although well into the 20th century many men (and women) became talented amateur artists. With scrimshaw, as elsewhere, experience was valuable and in this case the scrimshander was certainly proficient and adaptable as he dealt admirably with the particular difficulties of the skull. The scrimshaw images themselves have no great historical significance but as a whole the specimen is a very interesting find.

Conclusions

This paper documents for the first time (to our knowledge) a safe and effective method for cleaning osteological specimens exhibiting scrimshaw without damaging either the specimen or artwork, including the black pigment used in this case. Even extremely dirty bones covered in what were presumably, at least in part, 'sooty particulates' can be cleaned effectively and safely without damaging the scrimshaw artwork using minimal amounts of diluted Synperonic-A7 non-ionic detergent in distilled water. However, both care and time are required, and testing a small area first is essential as different sorts of pigments were used.

The cleaning facilitated the assessment of the scrimshaw artwork engraved upon the bone surface which enabled conclusions to be drawn as to the likely period of the scrimshaw and, by association, give an approximate likely date for the death and collection of the animal itself, in this case a rough-toothed dolphin. The level of the craftsmanship could also be assessed.

Whilst it is impossible to date most scrimshaw accurately, features of both images on this specimen suggest the artwork was executed between ca. 1830 and 1860, presumably not long after the animal was caught and de-fleshed. Due to the widespread distribrution of this species and the lack of any information about the specimen prior to its donation to the museum, the geographical location of its capture is completely unknown.

From the quality of the scrimshaw and the difficulties encountered in working on this particular sort of specimen, especially the cranium, it was most probably executed by an experienced and competent scrimshaw artist. However, the skull appears to have been new to him as he inadvertently exposed the diploe layer. It was not unusual for the mandibles from smaller cetaceans to be used for scrimshaw, but it is unusual to find scrimshaw on a skull.

The artwork on this particular dolphin skull and mandible is unusual not because of the skill with which it was executed but because the material is difficult to engrave well. In addition, scrimshaw artwork is normally presented on blank panels of bone or on single teeth, devoid of the rest of their osteological context. This specimen has had nothing removed and the two pieces of artwork remain in their original context on the skull and associated mandible. This is relatively rare and is of historical interest.

In the normal course of a whaling voyage it would have been unusual for a small toothed whale to have had its head removed, whether it was destined to provide meat alone or have its blubber used as well. However, from the mid-18th century there was an increasing interest in the natural world and especially in determining the relationships between organisms, and so in their classification: the natural order. Naturalists and scholars were and still are, keen to find new specimens. During the 19th century, museums were being built and natural history collections were growing. Whaling vessels were an excellent source of marine life and many whaling captains and the whaling surgeons who eventually sailed with them were interested in providing specimens. It is possible that the skull here discussed was 'commissioned' and offered as a dolphin specimen for anatomical study or to add to a collection. Perhaps one of the crew was an opportunist and took advantage of a new if awkward material to experiment with for his scrimshaw.

Acknowledgements

Thanks are due to Matt Lowe and to Adrian Friday, both of Cambridge University Museum of Zoology for helpful discussion, and to anonymous reviewers.

References

Dickens, G. 1957. *The dress of the British sailor*. London, HMSO & National Maritime Museum.

Dickens, G. 1977. *The dress of the British sailor*. London, HMSO & National Maritime Museum.

Hackney, S., Townsend, J., & Eastaugh, N. 1990. In *Dirt and Pictures Separated.* London: United Kingdom Institute for Conservation.

MacGregor, D. R. 1984. *Merchant sailing ships, 1815-1850.* London, Conway.

McCutcheon's, *Volume 1: Emulsifiers & Detergents,* North American Edition (2003) Glen Rock, NJ : Manu facturing Confectioner Publishing, McCutcheon's Division. *in Conservation*, Supplement 1, pp. 46-64 (19).

West, J. 1989. *Examining scrimshaw tools and techniques*. Unpublished research presented at the Kendal Whaling Museum (Sharon, Mass. USA). KWM archives.

West, J. 2000. The scrimshaw of Frederick Myrick: the rig and rigging of the whaling vessels Susan, Ann, Frances & Barclay ca.1829. *The American Neptune* 60 (4), 391-411.

West, J. & Credland, G. 1995. *Scrimshaw: The Art of the Whaler*. Hull City Museums & Art Galleries and the Hutton Press Ltd.

West, K. L., Mead, J. G., & White, W. 2011. *Steno bredanensis (Cetacea: Delphinidae).* Mammalian Species Volume 43, Issue 1:177-189, Published by the American Society of Mammalogists.

Winton, J. 1977. *Hurrah for the life of a sailor.* London, Michael Joseph.

Conservation of James Sowerby's Fungi Models

Arianna Bernucci & Lu Allington-Jones

Natural History Museum, Cromwell Road,
London, SW7 5BD

Corresponding author: l.allington-jones@nhm.ac.uk

Received: 26th Aug 2014
Accepted: 1st Nov 2014

Abstract

The Natural History Museum, London (NHM) holds 29 models of fungi created between 1796 and 1815 by the naturalist and illustrator James Sowerby. These models are interesting composites of painted unbaked clay, wood, metal and dried plant matter. This article outlines the techniques and materials used to clean, stabilise and re-house these model fungi. Remedial treatments were kept to a minimum but aimed to improve stability. They include the use of Lascaux for adhesion and consolidation, and the use of Groom/Stick® and smoke sponge for dry cleaning. The models were finally stored in bespoke acid-free cardboard boxes with inert foam inserts.

Keywords: James Sowerby; Models; Fungi; Remedial conservation

Introduction

James Sowerby (1757-1822) made many contributions to botanical works during his life-time, and also produced extensive volumes on mycology, conchology and mineralogy. Sowerby was one of the contributors to the first ever British botanical magazine, whilst one of his most famous works: "The English botany; or coloured figures of British plants *,* with their Essential Characters, Synonyms and Places of Growth", featuring nearly 2500 colour illustrations, is still regarded as an authoritative reference source. Sowerby differed from contemporary botanical illustrators in that he produced paintings for science rather than for a wealthy patron (Walsh ,2003). His other work includes "Coloured figures of English fungi or mushrooms*"* and the creation of 193 fungi models to educate the British public about poisonous species. Sowerby opened his home twice a month, inviting the public in to view the models and learn to identify those safe (and unsafe) to forage (Smith, 1888). The Natural History Museum bought the fungi models in 1844 from Sowerby's son, James De Carle Sowerby (Carruthers, 1888) but only 29 survived the extensive damage suffered by the museum collections during World War II (Tribe, 1995).

The majority of the surviving models are composed of unbaked clay mounted on metal armatures and coloured with oil paints. Smith (1888, 223) describes some of them as having parts fabricated from wire, wood, sheet iron, card and leather. He even notes that some models are 'the real fungi themselves, dipped in some hardening solution and then painted'. The models were originally mounted on blocks of wood, or sometimes cork, surrounded by real moss (Smith, 1888). In preparation for an exhibition at the NHM, Worthington G. Smith describes how he repainted the models using oil paints, and remounting them in a more 'natural' setting by surrounding them with dead leaves, branches, horse-dung, beech-nuts, and acorns (Smith, 1888).

The models are now suffering from deterioration due to their brittle substrate (possibly exacerbated by mercuric chloride or similar biocides), failed adhesives and poor storage conditions. Many of them are chipped, broken, cracked, abraded, have loose fragments or detached labels. It was decided that flaking paint and cracks would be consolidated and the models would be lightly cleaned. Due to the uncertainty of their restoration history, the areas of paint loss were not renewed.

Bernucci, A., & Allington-Jones, L. 2015. Conservation of James Sowerby's Fungi Models. *Journal of Natural Science Collections*. **2.** pp. 35-40.

Fig 1. Cleaning with smoke sponge and Groom/stick.

Methods for Repairing and Cleaning the Models

Discrete areas were cleaned using different techniques to establish a suitable method. These included dry brushing, localised vacuum, smoke sponge, Groom/Stick®, low-pressure air jet, distilled water and laser ablation. Dragging a smoke sponge (vulcanized rubber) gently over smooth surfaces, followed by dabbing with Groom/Stick® (natural rubber) was found to be the most appropriate method of cleaning (Fig 1). The Groom/Stick® was not found to leave a residue behind on the surface, as it can with some materials, when used in this light dabbing technique to remove the particulates. It was found to be impossible to clean the decoration on the mounts without causing damage. Repairs were made using Lascaux 498HV (acrylic adhesive): broken surfaces were dusted with a large soft brush to remove loose particles, consolidated with Lascaux 4176 (acrylic dispersion), and the adhesive was applied using a small brush. The two surfaces were then pressed together and allowed to air-dry. The cracks were consolidated by injecting 15% (v/v) Lascaux 4176 and deionised water (Fig 2). Lascaux was chosen for its workability, elastic strength, pH, ease of application, low toxicity, final appearance and long-term stability (Becker, 2014; Hedlund & Johansson, 2005; Millard, *et al*. 2011).

Methods for the Stabilisation of the Organic Substrate

The leaves and twigs which decorated the plinths were loose and becoming detached and lost every time the specimens were moved or air currents reached them. It was essential to stabilise these as part of the object. The most suitable method for stabilisation was established through tests on a variety of similar plant fragments which were collected from the museum grounds and then air-dried naturally within the laboratory. These dried stems, leaves and flower petals were placed on top of squares of acid-free card. Lascaux 4176 was applied to each group using a different technique: nebuliser, brush, spray bottle and pipette. A range of dilutions were also tested using these different styles of application. The tests aimed to discover a method that would strengthen the plant fragments and adhere them to the card bases, but that would not cause changes in lustre or colour.

The first test used a nebuliser to apply a mist of 100% solution of Lascaux 4176 to the plant fragments. This dilution proved too viscous to work effectively with the nebuliser, resulting in spits and dribbles rather than mist formation. A 25% concentration of Lascaux 4176 in distilled water was therefore used to generate a mist. The nebuliser proved difficult to control: Pointing it directly at an area caused loose material to be blown away, whilst tilting it caused the consolidant to bubble up and overflow. At greater distances the cloud dispersed before it had a chance to settle. A make-shift enclosure was constructed to allow settling and the nebuliser was used in repeated short bursts in an attempt to build up a sufficient layer (Fig 3). This worked well to give an even coating on the organic fragments and the resulting appearance was good, but it failed to adhere them to the card.

Fig. 2. (left) One of the models before treatment. (right) After cleaning, repair and consolidation.

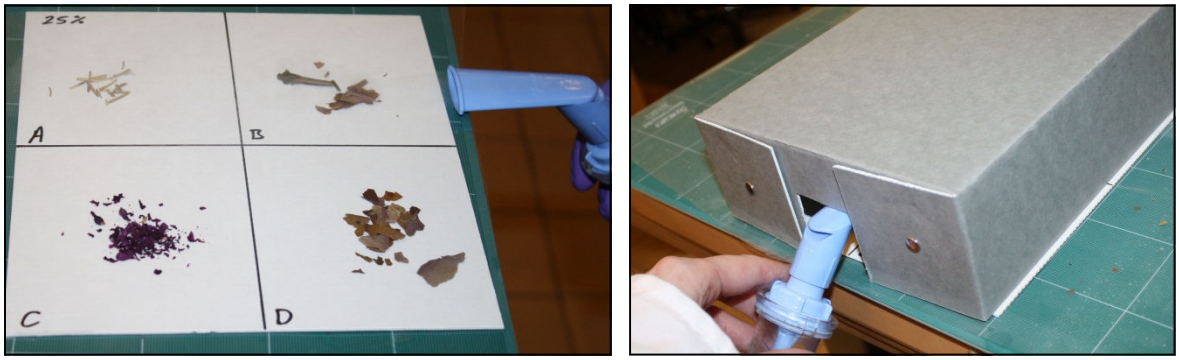


Fig. 3. (left) Consolidant cloud creation using a nebuliser. (right) Make-shift enclosure to prevent cloud dispersal.

A higher level of control was achieved by flicking consolidant onto the fragments with a brush. This technique resulted in a low penetration level and uneven coverage. Different concentrations of Lascaux 4176 were tested with this method, but the amount of dilution did not make a difference in appearance or success of the consolidant. Application with a spray bottle also proved unsuccessful because the force was too strong and it mostly blew the loose material around.

A pipette proved to be the easiest and most successful way of applying the consolidant. It provided the most control, coverage and penetration. The 100% and 25% solutions completely flooded the samples so lower concentrations were also tested. The most suitable dilution proved to be 15% Lascaux 4176 in distilled water: All of the material was consolidated into place and it had not gained a lustre or changed colour.

Re-housing the Models

The models had already been stored in acid-free boxes, as part of an earlier collections care project, but they were still vulnerable to physical damage (Fig 4). Many of the boxes were much too large for a single model, so in several cases multiple small objects were stored in one box. These could slide around and collide during transportation. The gaps between models were filled with tissue paper, causing abrasion if movement were possible, and compaction damage when packed too tightly. In addition, since the models could not be viewed without opening the lid and removing the tissue, the mass and weight distribution could easily be misjudged, leading to accidents.

An acid-free cardboard tray was therefore created for each individual model (the example can be seen in Appendix 1). This was lined with 2mm plastazote® foam (cross-linked closed cell polyethylene nitrogen expanded foam), to protect the model from vibrations. A snugly-fitting recess was then carved into 10mm plastazote in the shape of the footprint of the plinth. Finger-holes were cut on each side to enable access, although the low tray was designed to allow study without direct handling. An acid-free box was then created with a drop-down front to allow easier removal of the model, by sliding the low tray out horizontally, rather than lifting from above. The boxes were also given polyester windows to enable better-informed handling and transportation of the models when they are needed for research (Fig 5). The boxes were held together using nickel plated rivets from Conservation by Design. The cardboard used for this particular project was grey/white acid-free and lignin-free E-Flute corrugated boxboard (Conservation by Design). The polyester for the windows was 75 micron (Preservation Equipment Ltd.) and the double-sided tape used to position them prior to riveting was double-coated 3M #415 polyester transparent tape (Preservation Equipment Ltd.). This box design derives from best practise for general object storage developed over several years within the Conservation Centre at the NHM. All storage materials were chosen for their low chemical reactivity and have passed the accelerated aging test as described by Thicket & Lee (2004).

Fig 4. One of the previously existing storage boxes.

Fig. 5 Above: One of the new bespoke trays with cut-out foam.
Right: One of the new boxes which has a drop-down front. The window enables identification and aids handling.

The ideal storage environment for the models is problematic because they are composite objects. Table 1 below, shows a few of the contradictory recommendations for relative humidity found within the literature. In this case, the most sensible option was to choose 45 +/- 5% RH with as little fluctuation as possible (see references in Table 1). Lux and UV of the storage environment are at zero, to prevent fading and other photo-oxidative reactions. Temperature is managed at an achievable ideal of 21 +/- 3°C.

Material Type	Recommended RH	Source
Mixed Collection	55%	Staniforth, 1994, 237
	60-70%	Pye, 1994, 400
	40-55%	Stolow, 1987, 252
	45-55 or 50-60%	Thomson, 1997, 268
Iron	40-45%	Shearman, 1990, 21
	<50%	Wang, 2007, 126
	40-45%	Staniforth, 1994, 237
	15-40%	Stolow, 1987, 16
	<30%	Erhardt, *et al.* 2003, 155
Brittle ceramics	>40%	Erhardt & Mecklenberg, 1994, 37
Ceramics[(i)]	45-55%	Uprichard,1990, 30
	48-52%	Buys & Oakley, 1998, 30
	40-65%	Bradley & Daniels, 1990, 1
	55-60%	Daintith, 1994, 358
	20-60%	Stolow, 1987, 16
	0-45%	de Guichen, 1988, 68
Ceramics (with salts)[(ii)]	<55%	Erhardt & Mecklenberg, 1994, 34
Stone (with salts)	<60%	Munday & Dinsmore, 1990, 42
Stone (clay-rich)	30-40%	Bradley, 2005, 163
Organics	<70%	Florian, 2004, 54
	50-60%	Pye, 1994, 401
	50-65%	de Guichen, 1988, 68
	<60%	Erhardt, *et al.* 2003, 154
Adhesives[(iii)]	40-70%	Erhardt & Mecklenberg, 1994, 34
	<50%	Daintith, 1994, 358

Table 1. Some recommendations of ideal RH levels. Notes: (i) High temperature fired pottery is very durable, but poorly fired ceramics are fragile, because not all of the clay minerals have been altered (Uprichard 1990, 27). Unbaked clay is therefore very sensitive to fluctuation. (ii) Clay and ceramics which have been contaminated with soluble salts during burial are susceptible to flaking and crumbling under variable RH (Uprichard, 1990, 29). (iii) Polymers will craze, chalk, embrittle or become tacky, depending on environmental fluctuations (McNeill 1992, 14). This will affect joint strength, particularly important with brittle materials like unfired clay, prone to breakage if pieces fall.

Summary

Museums hold cultural heritage in trust for society and it is their duty to balance access with preservation for future generations. Historical collections, whether composed of actual specimens or representative information, like James Sowerby's fungi models, are a non-renewable resource. They hold value as comparisons against modern material, as a document of collectors and collecting, and often contain or represent species that are no longer extant or readily obtainable.

In addition these particular models serve to preserve fungi in 3-dimensions, as they appeared during life, augmenting information from illustrations and forms of preservation such as dried or spirit collections. Proper care and storage is therefore essential.

This project has ensured the stabilisation of the models, allowing them to continue to be used as a teaching collection, through the use of conservation-grade materials that reduce risk from handling but do not contribute to chemical deterioration.

Acknowledgements

Many thanks to Holger Thüs of the NHM for assistance with the project, and the reviewers and editor for their valuable advice on this article.

References

Becker, K. L. M., 2014. Treating friable matte pigments on bark: experimental analysis of four consolidants. *Journal of the Institute of Conservation.* Available at: www.tandfonline.com/doi/full/10.1080/19455224.2014.928644

Bradley, S., 2005. Preventive conservation research and practice at the British Museum. *Journal of the American Institute for Conservation*. **44(3).** pp.159-173.

Bradley, S. & Daniels, V., 1990. Environment. In: S. Bradley (ed.) *A guide to the storage, exhibition and handling of antiquities, ethnographic and pictorial art*. British Museum Occasional Paper 66. London: British Museum. 1-14.

Buys, S. & Oakley, V., 1998. *The conservation of ceramics*. Oxford: Butterworth Heinemann.

Carruthers, W. 1888. *Note on Sowerby's Models of British Fungi.* J. Bot., London. 268-269.

Daintith, C., 1994. Conservation and storage: ceramics. In: J. M. A. Thomson, D. A. Bassett, A. J. Duggan, G. D. Lewis and A. Fenton (eds.) *Manual of curatorship: A guide to museum practices*. Oxford: Butterworth Heinemann. 353-363.

Erhardt, D. & Mecklenbrg, M., 1994. Relative humidity re-examined. In: A. Roy and P. Smith (eds.) *Preventive conservation: Practice, theory and research*. London: International Institute for Conservation of Historic and Artistic Works. 32-38.

Erhardt, D., *et al.,* 2003. The determination of appropriate museum environments. In: S. Bradley (ed.) The interface between science and conservation. British Museum Occasional Paper 116. London: British Museum. 153-163.

Florian, M-L. E., 2004. *Fungal facts: solving fungal problems in heritage collections*. London: Archetype Publications.

de Guichen, G., 1988. *Climate in museums: measurement*. Rome: ICCROM.

Hedlund, H. P. & Johansson, M. 2005. Prototypes of Lascaux's medium for consolidation: development of a new custom-made polymer dispersion for use in conservation. *Restauro* **6.** pp.432-439.

Millard, T., *et al.* 2011. The conservation of 830 oil paintings on paper by Marianne North. *Journal of the Institute of Conservation*. **34(2).** pp.159-172.

Munday, V. & Dinsmore, J., 1990. Stone, wall-painting and mosaics. In: S. Bradley (ed.) *A guide to the storage, exhibition and handling of antiquities, ethnographic and pictorial art*. British Museum Occasional Paper 66. London: British Museum. 41-52.

Pye, E., 1994. Conservation and storage: archaeological material. In: J. M. A. Thomson, D. A. Bassett, A. J. Duggan, G. D. Lewis and A. Fenton (eds.) *Manual of curatorship: A guide to museum practices*. Oxford: Butterworth Heinemann. 392-426.

Shearman, F. 1990. Metals. In: S. Bradley (ed.) *A guide to the storage, exhibition and handling of antiquities, ethnographic and pictorial art*. British Museum Occasional Paper 66. London: British Museum. 18-26.

Smith, W. G. 1898. *Guide to Sowerby's Models of British Fungi in the Department of Botany, British Museum (Natural History)*. London.

Smith, W. G. 1888. *Sowerby's Models of British Fungi*. J. Bot., London. 231-233.

Staniforth, S. 1994. Control and measurement of the environment. In: J. M. A. Thomson, D. A. Bassett, A. J. Duggan, G. D. Lewis and A. Fenton (eds.) *Manual of curatorship: A guide to museum practices*. Oxford: Butterworth Heinemann. 234-245.

Stolow, N. 1987. *Conservation and exhibitions: packing, transport, storage and environmental considerations*. Boston; Durban; London; Singapore; Sydney; Toronto; Wellington: Butterworths.

Thickett, D. and Lee, L.R., 2004. *Selection of materials for the storage or display of museum objects*. British Museum Occasional Paper 111. ISBN 0-86159-117-8.Availableat www.britishmuseum.org/research/publications/reearch_publications_series/2004/selection_of_materials.aspx

Thomson, G. 1997. *The museum environment*. (2nd edition) Boston; Melbourne; New Dehli; Oxford; Singapore; Yohannesburg: Butterworth Heinemann.

Tribe, H. 1995. 'Fungi in London: some highlights over two hundred years'. *The London Naturalist.* **74.** pp.55-59.

Tribe, H. 1984. 'Sowerby's Models and 'Sowerby Inspriation Models''. *Bulletin of the British Mycological Society*. **18.** pp.61-64.

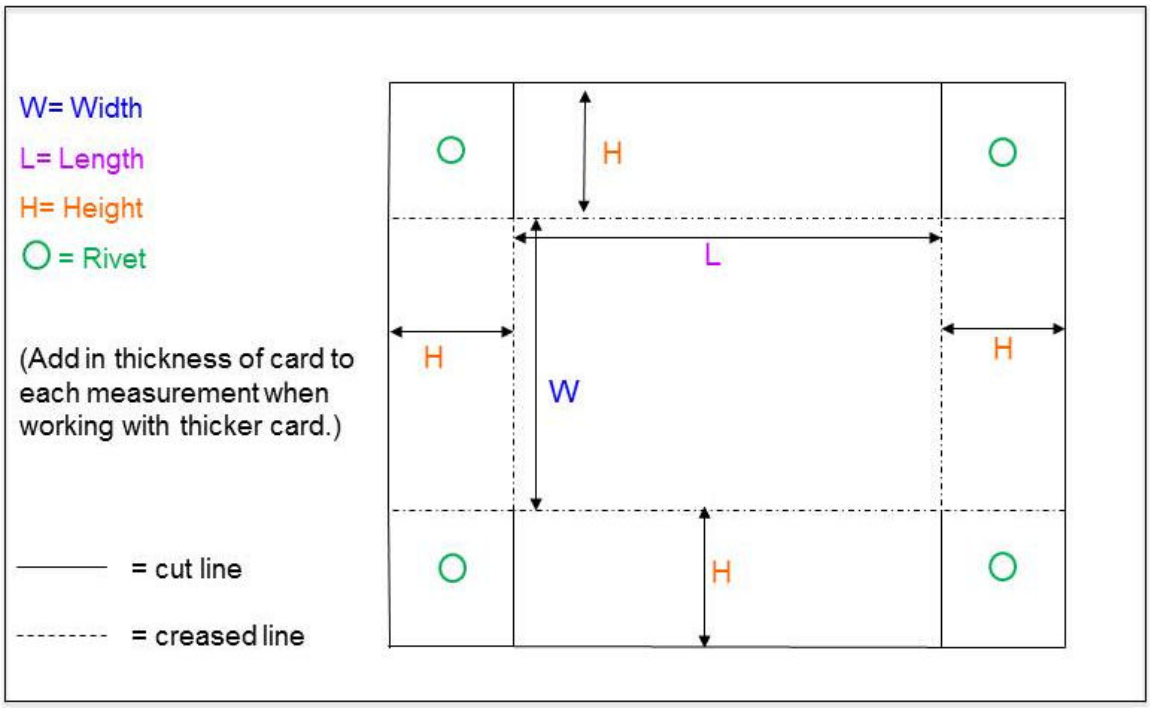
Uprichard, K. 1990. Ceramics and glass. In: S. Bradley (ed.) *A guide to the storage, exhibittion and handling of antiquities, ethnographc and pictorial art*. British Museum Occasional Paper 66. London: British Museum. 27-40.

Walsh, H. M. 2003. *James Sowerby 1757 – 1852*. Available at http://www.illustratedgarden.org/mobot/rarebooks/author.asp?Creator=Sowerby,+James&creatorID=94.

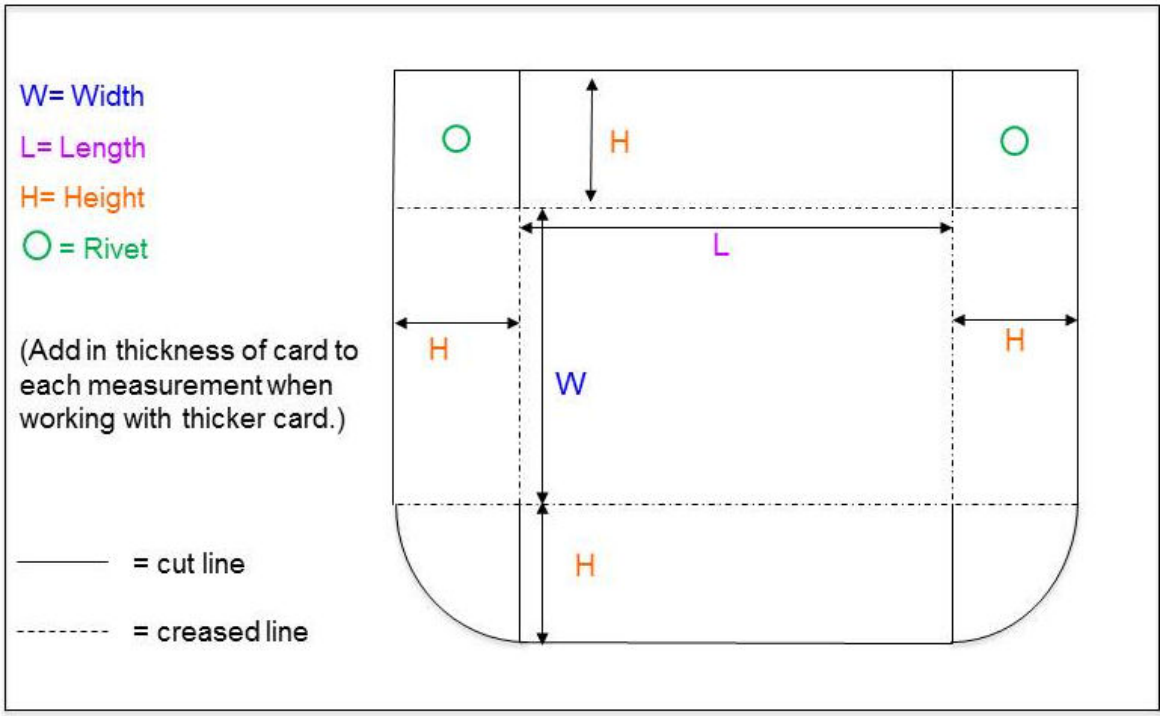
Wang, Q., 2007. An investigation of deterioration of archaeological iron. *Studies in Conservation*. **52.** pp.125-134.

APPENDIX 1.

The tray and lid template (developed by staff at the Conservation Centre, NHM)



The box template (the window can be cut into the front drop-down side of the box or into the lid, depending on storage style).



Exploitation of digital collection data at the Museum für Naturkunde Berlin

Saskia Jancke, Dirk Striebing & Frieder Mayer

Museum für Naturkunde - Leibniz Institute for Evolution and Biodiversity Science, Invalidenstrasse 43, 10115 Berlin, Germany

Corresponding author: saskia.jancke@mfn-berlin.de

Received: 14th Sept 2014
Accepted: 18th Dec 2014

Abstract

Item information for many collections in the Museum für Naturkunde Berlin (MfN Berlin) - as in many other museums - is often stored locally by each curator in different formats such as *Excel* spreadsheets. These files are often accessible exclusively by collection staff members. Within the project "Exploitation of digital collection data" funded by the Deutsche Forschungsgemeinschaft (DFG) the data from the MfN Berlin mammal collection were transferred from *Excel* spreadsheets to an SQL server using scripts developed by a database specialist at the MfN Berlin. The data were subsequently standardised (for example in terms of their taxonomic and geographical information) then transferred from the SQL server into *Specify* - a museum database software application. Further aims of this project are the development and implementation of common transfer tools to achieve data migration to open-access databases such as BioCASE and GBIF as well as information retrieval like the current distribution and protection status of the specimen from databases like the IUCN redlist. This will allow external information retrievals of collection data and thus will open new avenues for scientific exploration of the collections. We have successfully applied our data transfer pipeline to the mammal collection of the MfN Berlin which is the 4th largest of its kind worldwide. These methods and tools can be used for the data migration in other collections at the MfN Berlin with its approximately 30 million collection objects, and also by other museums.

Keywords: Collection Management System; Data Improvement; Data Retrieval; Data Transfer; Natural History Museum; SQL; Transfer Script; Mammalia; Open Source; Biodiversity Informatics

Introduction

The mammal collection of the Museum für Naturkunde Berlin (MfN Berlin) was founded about 200 years ago with the aim to collect specimen from all over the world. The collection originated with just arond 40 specimens from the cabinet of curiosities of the *Akademie der Wissenschaften* in the 18th century (Jahn, 1985). From 1816 onwards accessions were recorded in catalogues and while at first the collection grew very slowly (with rarely more than 100 specimen per year), soon this growth increased, and between 1906 and 1916 the annual accession rate comprised on average 3,500 new specimens (Angermann, 1989).

The collection grew so fast that it was not possible to keep record of all accessions. In 1926 the general collection catalogue contained 35,693 entries which meant that considerably fewer specimens were recorded in the catalogue than were present in the collection (Angermann, 1989). Specimens came from all over the world and were collected during expeditions or sent by Germans living abroad, bought from traders or professional collectors, exchanged with other Museums, or were given by the *Zoologischer Garten* in Berlin. Many new species were described during these early days and the collections hold many type specimens. It is estimated that the mammal collection of the MfN Berlin currently has around 150,000 specimens. Most of the information was kept on the specimen labels and partly in accession catalogues.

Jancke, S., Striebing, D., & Mayer, F. 2015. Exploitation of digital collection data at the Museum für Naturkunde Berlin. *Journal of Natural Science Collections*. **2.** pp. 41-46.

After the Second World War, a large amount of skins were in very bad condition due to penetration of rain water and high humidity in the collection rooms. Labels became illegible or got lost during cleaning processes; the information loss often meant academic devaluation of the specimen. Furthermore original expedition and collection lists as well as the taxonomic catalogue were lost during this time. Another problem originated from the practice to send only skins to the Zoological Museum while the skeleton, skulls and alcohol material of the individuals went to the anatomical collection of the medical faculty. However, in the anatomical collection no information on the collector, collection date, nor the locality was recorded which meant a great loss of information. Both collections were recombined later (Angermann, 1989) and only with great effort, all collected body parts could subsequently be associated to one individual and inventoried with one definite catalogue number.

About 50 years ago specimen information sorted by the inventory number from the accession catalogues started to be transcribed on file cards to facilitate research on the specimens for requests. File cards were sorted by taxonomy. 10 years ago this information started to be transferred to excel spreadsheets, one for every mammal order. These spreadsheets contain the information on the inventory number, taxonomy, preparation, locality, determination, collector, collection date as well as accession. These excel lists are continuously updated and amended. To date about 79,000 specimens are inventoried which comprises about half of the specimens in the mammal collection and the improvement of collection data and inventories are ongoing.

The Natural History Museums collections hold very valuable specimens and specimen information for scientists of different disciplines such as taxonomists, ecologists, evolutionary biologists, geneticists, paleontologists, archaeologists, as well as historians, etc. Information is frequently requested for various types of studies such as recreating the historic distribution of species or the genetic analysis of rare or even extinct species. On one hand we have important data which are often locally based with the files accessible exclusively by collection staff members. On the other hand we have global online biodiversity databases such as GBIF or BioCASE which provide an important open-access research infrastructure. However, the data transfer from locally hosted museum databases or spreadsheets to these open-source biodiversity databases is seldom accomplished. Here we developed a framework to allow the data transfer from museum's collections to open access databases. This will allow external information retrievals of collection data and thus will open new avenues for scientific exploration of the collections.

Methods

To allow the data transfer from museum collections to open access databases, the data needed to be stored in consistent data formats in SQL databases. At the MfN Berlin we use the collection management system *Specify* developed by the University of Kansas, which is an open source database system with a MySQL database backend and a Java application frontend.

A further aim was to develop transfer tools so that the data could also be stored in open-access databases such as BioCASE & GBIF allowing external information retrieval of collection data such as the species distribution or protection status e.g. from the IUCN webpage.

We developed the following methods to accomplish these goals (Figure 1, below we discuss these steps in more detail):

1. Pre-Importation of collection data from excel spreadsheets into a Microsoft (MS) SQL-database.
2. Standardisation of data and improving data quality using MS Access as the front end. Eradicating/removing double entries and duplicate inventory numbers so that every specimen is recorded explicitly and completely.
3. Transfer of the improved data to a MySQL database and final error checking.
4. Develop the transfer tools to transfer data from the SQL database to *Specify*. Transfer of the collection data into *Specify* 6.
5. Develop the transfer tools for the data transfer between *Specify* and open access biodiversity databases such as GBIF and BioCASE.
6. Develop the transfer tools to retrieve data such as the protection status and distribution from the IUCN webpage.

As a first step, the mammal collection data stored in excel files were transferred to a MS SQL database to bundle all conflicts. Using an MS Access frontend, the data were reassessed in terms of taxonomy (correct and valid species name based on the taxonomy of Wilson & Reeder, 2005), locality (update the locality information which was a challenge especially for all the old colony names and changing frontiers since the collection date), eradicating spelling mistakes and number duplicates.

The geographic tree from *Specify* was used as provided by the developers to allow for continuous and automatic updates. The geography was then automatically related to the locality data where possible, while conflicts were solved manually in MS SQL. Where possible the localities were related to modern countries, while border regions were defined as new countries, e.g. the region Abessinia reaches from Ethiopia to Eritrea, so the newly defined country would be Ethiopia/Eritrea. Historic locations were researched using the collectors' itinerary information where possible, researching place names

online and specifically on getamap.org. Occasionally the locality and collector's information previously researched by a colleague from the ornithological collection was used as well.

This pre-import was an important step for the data validation but it was independent from the import solution. For the *Specify* import an import database was used which is on the same server, a MySQL server, as the *Specify* database. The data were transferred from the pre-import MS SQL database to the MySQL import-database using simple SQL-insert-commands which can be used on all platforms. The import-database consists of tables with fields from *Specify* in a 1 to 1 relationship. There are different tables for different information with fields such as determination, collector, or location. Some fields have several alternatives with different precisions or formats, e.g. the information on a collection date can be stored in a field for a complete date as well as two further fields for month and year. Subsequently, all the field values were distributed into their respective target fields.

The taxonomy was imported first to *Specify*, so that a taxonomic tree was already available in the database before the specimen data were imported. The taxonomy included a list of all valid species names from the Catalogue of Life including the synonyms, and was completed with the information from the Wilson Reeder taxonomy (Wilson & Reeder, 2005) and stored in a CSV file.

Results

Originally 86,478 specimens were recorded in 30 excel spreadsheets (one record per row) for the mammal collection in the MfN Berlin. During the data transfer process of the specimens recorded in the excel spreadsheets, duplicate or indefinite entries were eradicated, so that subsequently 78,775 valid specimens were recorded in the new *Specify* database. Indefinite entries were mostly duplicates or different body parts which were recorded separately in the spreadsheets but identified as one individual during the data improvement process in the MS SQL database.

The excel spreadsheets consisted of 26 columns with information on taxonomy, locality, collecting information, remarks and an identifier. Information stored in these fields was transferred into 49 definite fields in *Specify*.

The data transfer was completed within one year. The limiting step was the improvement of data quality. However, this was simply done based on the data already entered. If data were transcribed incorrectly from the specimens labels into the excel spreadsheets, i.e. localities or collectors were misread on the label when entered into the excel spreadsheets or if the transcription was faulty, it was not possible to correct this during the project year. Furthermore, if specimens were determined incorrectly and the information on the determination in the spreadsheet therefore incorrectly, a correction during the course of the project was impossible

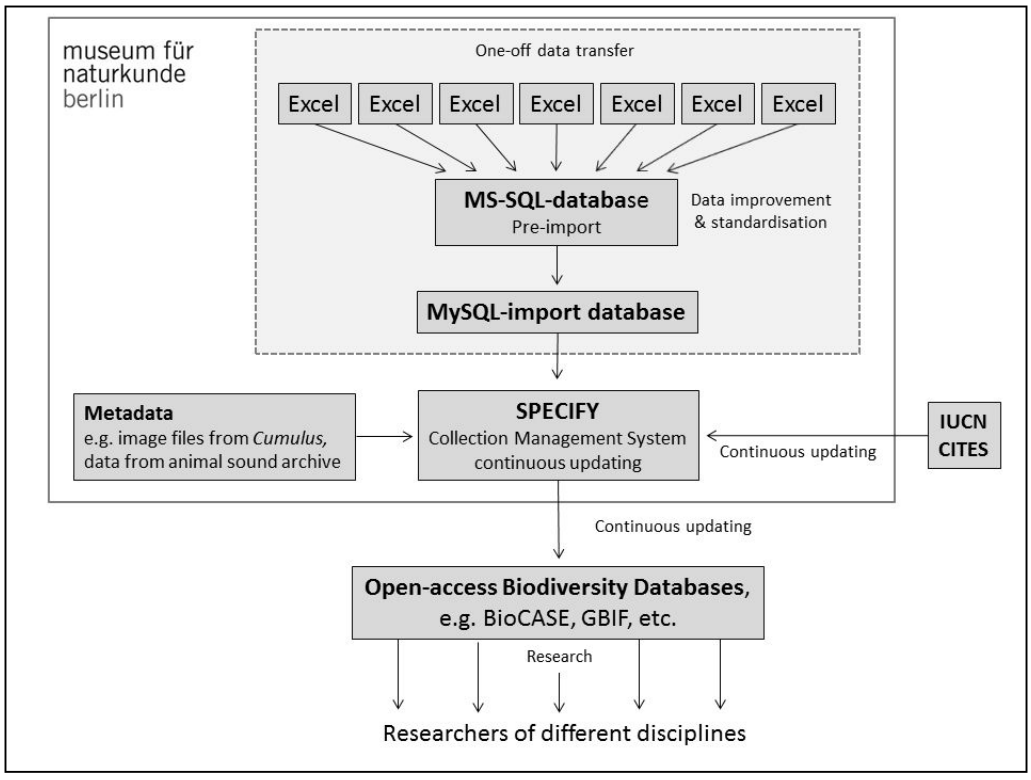


Fig. 1. Workflow of the data transfer process.

as this would have required accessing every specimen to check them as well as the information on the labels.

However, it was possible to improve a great amount of data e.g. in terms of locality or taxonomic information. Locality information in the excel spreadsheets was often transcribed from the specimen label and entered into two fields in excel: "locality name" and "present locality name – country". If locality names were misspelled or not up-to-date (like e.g. old colonial names) the information was updated during the data improvement step in the MS SQL database. Some specimens came from the same locality and the advantage of using an SQL database is that this information can be cumulated. Accordingly the 78,775 specimens were bundled in terms of the geographical information and resulted in 20,950 different localities. It was then updated during the data improvement process after the pre-import to the MS SQL database. The localities described in the excel spreadsheets were researched and if the research was successful, the modern locality name was noted together with the affiliation to the modern country, continent etc. For 9,026 localities (43%) the information was explicit and could be transferred automatically into the *Specify* schema, while the remaining locality information had to be updated, improved and standardized before the data could be transferred.

For example, the information:
Locality name: "Amani, Usambara, D.O.A." - had to be updated and standardized before a data transfer was possible.
An example for an explicit data entry which could be transferred automatically is:
Locality name: "Potsdam" and *Present locality name - country*: "Germany".

The mostly historic locations were related to 290 countries from all 7 continents. Oceans and seas were defined as new continents which were not already present in the geographic tree existing in *Specify*.

Another aim was to validate the taxonomic information. Of altogether 3,980 different taxa, 962 taxa were updated manually in the MS SQL database following the systematics of Wilson & Reeder (2005). 2,117 type specimens were entered in the database, 383 of which were holotypes.

In terms of data standardization e.g. 11,650 collection dates were standardized. Dates can be described in different formats in excel when the field is not defined as a date field as it was the case for the mammal collection data. Information can be written inconsistently (e.g. already the month of a date can be recorded in different formats such as "3", "03", March or German März). These dates were standardized and if information was missing (e.g. only March 1906 was recorded), the information was put into fields describing incomplete dates (month: March; year: 1906).

Also the preparation (skull, skeleton, skin, and alcohol material), determination, as well as the collector/accession were standardized for the import so that all information was spelled correctly, consistently, and subsequently put into definite fields.

Since the transfer of the mammal collection data further transfers have already been completed such as data of the embryological collection stored in CSV files as well the data of the collection of Orthoptera which were kept in a FileMaker database. In the historical department additional information on portraits were added from excel spreadsheets to the existing information stored in the archiving SQL database system LARS (Leistungsstarkes Archivierungs- und Recherchesystem). For these imports the scripts from the mammal collection data transfer were used. These imports profited directly from the experience made by our data transfer to Specify and no additional time for developing these scripts was needed.

Discussion

Scientific collections are of great value for biodiversity and collection data are an important research infrastructure (e.g. Türkay, 2011; Lister *et al.,* 2011). It is good research practice to keep all the primary information on the specimens in a database and this database increases exponentially in utility when it is globally accessible (Türkay, 2011). There is a great interest in opening up natural history collection data to the wider community as show by European projects like *Open up!* (Berendsohn & Güntsch, 2012).

Excel spreadsheets were the first way of digital data capturing and storage in the mammal collection in the MfN Berlin. The spreadsheets contained all information on taxonomy, locality, preparation, accession as well as the inventory number, and were continuously added and updated. The problems that come with this excel spreadsheets are 1) updates have to be done per record and 2) inconsistencies in data entry (e.g. sex can be female, Female, F, f, fem. etc.) which makes it more difficult to search for definite terms. If the taxonomy changes or a historic locality has been researched, updates can't be done cumulatively. Inconsistencies in spelling and misspelling are also likely sources of error. A database like *Specify* offers a solution as updates can be done cumulatively, sources of errors are reduced by accessing information from the taxonomic or geographical tree, and inconsistencies in spelling are reduced if updating is done cumulatively or by using a predefined selection (dropdown list). This reduces the workload for the collection staff considerably.

Specify offers an import tool in the Workbench where excel files can be imported directly into the database. However, the data transfer into *Specify* is eventually planned for all collections in the MfN Berlin. The scripts which were developed in this project to transfer data between different Microsoft applications such as excel but also from other data-

base systems to MS SQL can be used for various collections. Another important aspect of the data import was to create a taxonomic tree based on the Catalogue of Life and the Wilson & Reeder (2005) taxonomy including the valid taxonomic names as well as the synonyms. Importing synonyms into the database using the *Specify* Workbench was not technically feasible and the pre-import to the My SQL database therefore necessary.

In the MS SQL database the conflicts were bundled as well as their solutions. For example, in our spreadsheets the information on the locality where the specimen was found was stored in just one field, including e.g. the country, town or location, sometimes in rare occasions also the georeferences. This information had to be transferred to definite fields like one for the country, one for the continent, etc. Data improvement and standardization was the most time-consuming task due to the number of specimens, therefore to bundle the conflicts was essential to allow the data transfer from excel into *Specify* with reasonable time effort. After the data improvement on the MS SQL server, data were transferred to a MySQL server. The import scripts were written for MySQL and can also be used by other institutions and users who want to import data to *Specify*.

The data standardization and improvement was done in MS SQL, however, it could have been equally done in MySQL. There are several reasons why this intermediate step was used at the MfN Berlin: 1. MS SQL server have been used for many years at the MfN Berlin and the database staff has expert knowledge in writing scripts for MS SQL; 2. MS Access used as a frontend is an user friendly and unproblematic tool to access SQL data; 3. Microsoft extensions such as Transakt-SQL provide further applications, e.g. Table-Valued functions and it allows recursive function requests.

Subsequently, important applications were translated for MySQL users and provided for download via the GitHub link under references. In January 2015, the MS SQL and MySQL import scripts can be downloaded from the following link: https://github.com/mfn-berlin/Sp6ImportDB/tree/master.

Tools such as the BioCASe Provider Software to connect databases such as *Specify* to open-access databases like GBIF and BioCASE were already developed (Glöckler, *et al.,* 2013) and once the data are unlocked automatic updates will allow external users to screen and retrieve the data of the mammal collection. It is planned to transfer the first mammal collection data of the MfN Berlin in year 2015 when an ongoing locality-georeferencing project has been completed.

One important part of providing digital access to natural history collection data are the quantitative geospatial references of biological collection data because they provide a quantitative basis for biodiversity analyses (Beaman, *et al.,* 2004). Retrospective georeferencing makes collection material more valuable because this allows spatial analysis (Murphey, *et al.,* 2004). Subsequently, our next step is to georeference the collection material of the mammal collection following best practice (Chapman & Wieczorek, 2006; Wieczorek, *et al.,* 2012).

However, historic locations are often difficult to put into a modern context. Researching the expedition routes as well as georeferencing old maps and locality names will subsequently provide important information on former distributions of species. In the past collectors were not just interested in one taxonomic group but a wide range of collectables, and during one field trip they would collect birds as well as mammals or even ethnological examples. Exchanging the already researched information for example on an institutional or even national or international level using a collectors and historic localities database saves time and efforts for museums staff. This is another potential use of the data stored in *Specify* as the locality information in relation to the collectors information can be retrieved and provided potentially in a specific collector's database.

First experiences of using *Specify* as the collection management system in the mammal collection show the important advantage of such a tool particularly for queries concerning e.g. localities and collectors, and especially where more than one taxonomic order is involved. In the past answering these queries was more time consuming using excel spreadsheets firstly because several spreadsheets had to be searched and secondly due to the inconsistencies in spelling and in defining localities and collectors. However, the very detailed structure of *Specify* with varies information stored in numerous but definite fields can cause problems when searching for unstandardized information. Information unspecific or unspecifiable for one field can be stored in different remarks fields. This information is then difficult to localise when creating a query. However once standards for the data entry for this kind of unspecific information has been developed and queries have been refined, the advantage of using a SQL database system will prevail. Another great advantage of using a collection management system such as *Specify* especially for the mammal collection in the MfN Berlin is that different body parts such as skull, skeleton, skin or alcohol material which was by mistake inventoried using different inventory numbers can now more easily be identified as one specimen using versatile filter options and due to standardised information of localities and collectors.

In summary using the transfer tools and data standardisation processes specifically developed during this project, it was possible to complete the data transfer of the comparatively large amount of mammal data successfully within a reasonable timespan of one year including a considerable improvement of data quality.

Acknowledgements
The collection managers Nora Lange and Christiane Funk of the mammal collection MfN Berlin as well as Pascal Eckhoff of the ornithological collection for providing data; Falko Glöckler and Dieter Korb for technical advice and Emma Berdan for linguistic help. This project was funded by the Deutsche Forschungsgesellschaft (DFG).

References

Angermann, R. 1989. Die Säugetierkollektion des Museums für Naturkunde der Humboldt-Universität zu Berlin, *Säugetierkundliche Informationen*, **3 (13).** pp.47-68.

Beaman, R., Wieczorek, J. & Blum, S. (2004) *Determining Space from Place for Natural History Collections*. D-Lib Magazine May 2004. **10 (5).** [Online], http://www.dlib.org/dlib/may04/ b e a - man/05beaman.html [accessed 23 July 2014].

Berendsohn, W. G., & Güntsch, A. 2012. OpenUp! Creating a cross-domain pipeline for natural history data. *ZooKeys*. **209.** pp.47-54.

Biological Collection Access Services (BioCASE) http:// www.biocase.org/ [accessed 02.12.2014]

Chapman, A. D. & Wieczorek, J. (eds.) (2006) *Guide to Best Practices for Georeferencing,* Copenhagen: Global Biodiversity Information Facility.

Global Biodiversity Information Facility (GBIF) http:// www.gbif.org/ [accessed 02.12.2014]

Glöckler, F., Hoffmann, J., & Theeten, F. (2013) The BioCASe Monitor Service - A tool for monitoring progress and quality of data provision through distributed data networks, *Biodiversity Data Journal* 1: e968.

Jahn, I. 1985. Zur Vertretung der Zoologie und zur Entwicklung ihrer institutionellen Grundlagen an der Berliner Universität von ihrer Gründung bis 1920, *Wissenschaftliche Zeitschrift der Humboldt-Universität Berlin, Reihe Mathematik/ Naturwissenschaften*. **34(3/4).** pp.260-280.

Lister, A. M. & Climate Change Research Group, 2011 Natural history collections as sources of long-term datasets. *Trends in Ecology & Evolution*. **26(4).** pp.153-154.

Murphey, P. C., *et al*. 2004. Georeferencing of museum collections: A review of problems and automated tools, and the methodology developed by the Mountain and Plains Spatio-Temporal Database-Informatics Initiative (Mapstedi), *PhyloInformatics*, **3.** pp.1-29.

Türkay, M. 2011. Wissenschaftliche Sammlungen: Unersetzbare Ressource der Biodiversitätsforschung, *Senckenberg: Natur,Forschung,Museum*, **14 (3/4).** pp.66-73.

Wieczorek, J., *et al.* (2012) *Georefer- encing – Quick Reference Guide* [Online], https:// w w w . i d i g b i o . o r g / w i k i / i m a g e s / 1 / 1 e / GeoreferencingQuickReferenceGuide.pdf [accessed 17 July 2014].

Wilson, D. E. & Reeder, D. M. (eds.) 2005. *Mammal Species of the World*. *A Taxonomic and Geographic Reference*, (3rd edition), Baltimore: Johns Hopkins University Press.

100 years of deep-sea tubeworms in the collections of the Natural History Museum, London

Emma Sherlock, Lenka Neal & Adrian G. Glover

Life Sciences Department, The Natural History Museum, Cromwell Rd, London SW7 5BD, UK

Corresponding author: e.sherlock@nhm.ac.uk

Received: 14th Sept 2014
Accepted: 18th Dec 2014

Abstract

Despite having being discovered relatively recently, the Siboglinidae family of polychaetes have a controversial taxonomic history. They are predominantly deep sea tube-dwelling worms, often referred to simply as 'tubeworms' that include the magnificent metre-long *Riftia pachyptila* from hydrothermal vents, the recently discovered 'bone-eating' *Osedax* and a diverse range of other thin, tube-dwelling species. For a long time they were considered to be in a completely separate Phylum, the Pogonophora, but with the discovery of a segmented posterior and then conclusive DNA evidence, they were restored to the Phylum Annelida. In this project curation and research teams have combined to enhance the Museum's collection. This has been facilitated through targeted donation requests, comprehensive digitisation, a location move to the rightful taxonomic place and teaming up with global database initiatives to promote the collection.

Keywords: Siboglinidae; Polychaeta; Annelida; Pognophora; Digitisation; Systematics; Curation

A brief taxonomic summary of the Siboglinidae

The taxonomic group currently known as the polychaete family Siboglinidae (Fig. 1) was discovered 100 years ago (Caullery, 1914). In a small laboratory in France, Maurice Caullery erected a new genus for a long thin worm, notably without any obvious mouth or gut, discovered from material collected on the Dutch Siboga expedition of 1900 from Indonesia (Caullery, 1914). The author did not place the new species in any higher taxon, but did compare it to deuterosomes such as pterobranchs and enteropneusts (Pleijel, *et al*., 2009). 100 years of argument has since ensued as to the true evolutionary placement of these enigmatic animals, and their discovery at deep-sea hydrothermal vents in the late 1970s has questioned the very nature of where complex life might exist in our solar system and beyond (Van Dover, 2000).

Scientific discussion as to the placement of these worms started when another similar gutless worm *Lamellisabella zachsi* was placed within the polychaete family Sabellidae (the feather-duster worms) (Uschakov, 1933). This placement of these worms in the correct phylum and class (if not family) was short-lived however. By the 1970s workers such as Ivanov (Ivanov, 1963) had made a good start on an almost lifetimes work of describing new species of these gutless worms within a new Phylum: Pogonophora. These workers were absolutely convinced that the worms were not related to annelids, had a dorsal nerve cord and radial cleavage during development, thus placing them within the deuterostome group advocated by Caullery back in 1914.

Sherlock, E, Neal, N & Glover, A., G. 2015. 100 years of deep-sea tubeworms in the collections of the Natural History Museum, London. *Journal of Natural Science Collections.* **2.** pp. 47-53.

For a mud-dwelling marine worm from the bottom of the ocean, siboglinids have a good history of making newsprint headlines. In 1955, the Natural History Museum in London (NHM) became involved in the debate when the museum Director Sir Gavin Rylands de Beer published a short paper in the journal *Nature*, clarifying 'reports in the Daily Press…' as to the discovery of a new phylum of animals (the Pogonophora) in Russia (de Beer, 1955). In 1958, British Zoologists Alan and Eve Southward published the first report of *Siboglinum* from the continental slope off the British Isles, again in the prestigious journal *Nature* (Southward & Southward, 1958). Then in 1964, a series of studies showed that the pogonophore worms had a unique feature that nobody had found before – a posterior segmented section, anchored in the tube with small hook-like chaetae (Webb, 1964). This was the beginning of the end for Pogonophora as a phylum, but it took a wealth of developmental, anatomical and genetic studies to finally place these animals back where they had started.

The story is well documented elsewhere (Pleijel *et al*., 2009, Hilario *et al*., 2011), but relevant to the Natural History Museum story is the work of David George in the early 1970s who made the first SCUBA observations (Fig. 2) on populations of *Siboglinum fiordicum* that had been discovered in remarkably shallow depths (35m) near Bergen, Norway (George, 1975, 1977). The observations of the larval behaviour from these studies were suggestive of polychaete (protostome) rather than deuterostome ancestry.

The discovery of the giant hydrothermal vent tubeworm *Riftia pachyptila* in the late 1970s and their description within the Vestimentifera class of the Phylum pogonophora, threw the group again into the newspaper headlines. At the same time, it seemed to reinforce their 'unique' position, given the discovery of their unique method of feeding – via chemoautotrophic bacteria housed inside their bodies gaining energy from the vent chemicals. But eventually, a wealth of DNA studies in the late 20th century (reviewed in Pleijel, *et al.*, 2009 and Hilario, *et al.,* 2011) have convinced the doubters what many had long suspected – the entire pogonophoran and vestimentiferan group were in fact highly-derived deep-sea polychaete worms in the family Siboglinidae.

The most recent twist, and news headlines, in the story of siboglinids has been the discovery of a third group of siboglinids, *Osedax*, found living on the bones of decaying whales at the deep seafloor (Rouse et al. 2004, Glover et al., 2005). These animals, thought to be closely related to the frenulate-type tubeworms (the original long thin worms described by Caullery) also lack a gut, but are able to utilise bacteria in a root structure to extract energy from rotting whale-bones, a remarkable and hitherto undocumented type of microbial association.

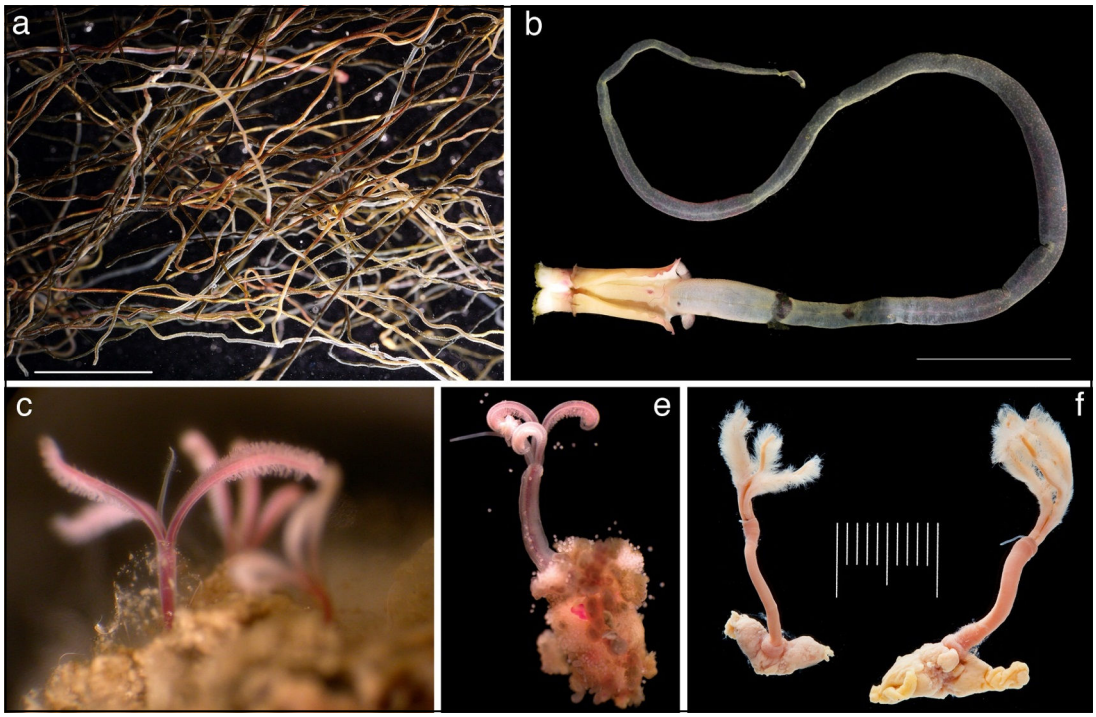


Fig. 1. Siboglinidae (Annelida), formerly within the Phylum 'Pogonophora'. (a) Thin tube-dwelling pogonophore worms recovered from Antarctic sediments (scale bar 1cm), (b) vestimentiferan-type cold-seep tubeworm (scale bar 3cm), (c) *Osedax mucofloris* growing on a whale bone, (e) *Osedax mucofloris* dissected out from whale bone, (f) *Osedax rubiplumus* donation to the NHM from Dr Greg Rouse, Scripps Institution of Oceanography. Images (a -e) by Adrian Glover, (f) by Natural History Museum Photo Unit.

Fig 2. The first Natural History Museum SCUBA dive team was setup in the 1960s, here diving at the 35m *Siboglinum fiordicum* depths in the early 1970s. Early observations of living siboglinids were an important clue in understanding their evolutionary history. Photo by Dr David George.

Introduction to the Natural History Museum polychaete collections

The polychaete collections at the NHM started out life, as did all the earliest of the NHM specimens, as part of the British Museum in Bloomsbury. In 1865, the British Museum produced a 350-page bound catalogue of the British non-parasitical worms, a book containing lengthy descriptions and fine hand-drawn plates, with the majority of the book dedicated to the class Polychaeta within the Phylum Annelida (Johnston, 1865). The polychaetes had been housed with the Mollusca collection under the care of E A Smith (Curator, 1867-1876), but in 1881 the new museum in South Kensington was opened and the polychaetes were moved there now under the care of Francis Bell (Curator, 1876-1912).

In 1912, Arnold Baylis took charge and set up the Annelida section for the first time and the profile of polychaetes within the collection would continue to rise. From 1922-1939 Charles Monro was head of the Annelida section and a polychaete worker himself. During his time in charge the number of depositions to the collection would rise dramatically (in 1920 less than 100 polychaetes were accessioned, in 1926 approximately 300 specimens were accessioned and in 1927 over 400 specimens were accessioned. (Natural History Museum, 1920-1927).

Progress continued with Norman Tebble (Curator, 1950-1961) and then Reginald Sims (an Oligochaete researcher) who was the annelid collections manager from 1961-1985. During this period (in 1968) the annelid section was split with the clitellate annelids (e.g earthworms, leeches) staying with Sims while David George managed the Polychaeta (and Porifera) sections. It was also in this year that David George set up the diving group in the Museum. This again led to a rise in specimen additions to the collection and rise in profile for the polychaete group. By the early 1970s one focus for David George and his diving team was the study of the pogonophores, as they were then known. In 1974 Alex Muir arrived at the Museum and worked on the collections under David George as well as later on a range of polychaete systematic studies (Chambers & Muir, 1997). In recent decades polychaete researcher Gordon Paterson made a large contribution to our understanding of polychaete biodiversity and taxonomy, with particular emphasis on deep-sea habitats (e.g Paterson, *et al.*, 1988; Paterson, *et al.*, 2009). Recent research programs led by one of the authors (AG) have focussed on deep-sea biodiversity, Antarctic biodiversity and in particular studies of whale-fall siboglinids including *Osedax* (e.g Glover, *et al.*, 2005, Glover, *et al.*, 2013).

Introduction to the Siboglinidae research and collections at the Natural History Museum

The pioneering work of Eve and Alan Southward led to the first major deposition of type material at the NHM in the 1950s. The first deposited specimens were syntypes *Siboglinum atlanticum* 1958.8.28.1 and *S. inermis* 1958.8.28.2-3 (Appendix 1). There are now 66 registered specimens in total, representing 33 different species (Appendix 1). An important aspect of the collection is the large proportion of types (51 of the 66, or 77%), particularly the result of the work of the Southwards and later George and now Glover and colleagues. A strength of the collection is the coverage of type material from all types of siboglinid habitat including vent-dwelling large tubeworms, the frenulate (pogonophore) type mud-dwelling worms and most recently the bone-eating *Osedax*.

In the 1970s, David George made a contribution to the debate on pogonophore systematics particularly with collections made with his newly-formed diving team (George & Southward, 1973; George, 1975; George, 1977). During this period he was able to establish that the *Siboglinum* larvae swam with their central nerve cord situated ventrally. This was a real breakthrough in the breaking down perceived barriers between the pognophore and annelid anatomical studies (George, 1975), but it took another 20 years for this theory to be accepted.

In recent years, Adrian Glover has been part of a team which led to the discovery of a number of new *Osedax* species. In 2005 Glover and colleagues described a new species, *Osedax mucofloris* (literally, the 'bone-eating snot flower') from remarkably close to one of the best studied marine

habitats in the world – the Skagerrak of the North Sea on the west coast of Sweden (Glover, *et al.*, 2005). This was the first shallow-water *Osedax* species to be described, following the original description of the genus from almost 3000m in the north-east Pacific in 2004 (Rouse, *et al.*, 2004). Glover has since worked up a number of further species descriptions, including the first Antarctic specimens, expanding the geographic range of the genus (*O. antarcticus*, *O. crouchi*, *O. deceptionensis*, *O. nordenskjoeldi* and *O. rogersi*). Given that the NHM polychaete research group have been at the forefront of recent discoveries of Siboglinidae, the Annelida curator (Emma Sherlock) teamed up with the researchers to bring the collections in line with 21st century discoveries.

Enhancing the collections

The collections at the NHM are large and their coverage very broad. However, to keep collections relevant, useful and current, they need to be not only well maintained but also updated and enhanced. Passively the collections are being enhanced every year through donations from collectors and researchers worldwide. However, to be of maximum benefit to the users certain areas of the collection, either with historical strength or research importance have been targeted as areas for active enhancement, to create areas of excellence within the collection.

The Siboglinidae has been chosen as one of these target groups. In order to make the NHM Siboglinidae collection as comprehensive as possible, deep-sea biologists were approached with a donation request from the museum. In some cases exchanges are being organised, with duplicate material housed within the museum where possible. Not only does this help the research team, but it also encourages visits from other researchers worldwide. A physical move was also required for the material already present, from the Minor Phyla store to its rightful position within the polychaete collections.

The collection needed to be accessible to the international research community, as well as other users of the collection such as exhibitors and educational projects, particularly in this digital age. To facilitate this, a database update needed to be completed. The older specimens in the collection were housed under Minor Phyla in the collections database, whilst the newer acquisitions were under Annelida. This meant some of the collections were 'virtually hidden' from the research community. This has now been updated. The type material has been professionally photographed, with JPEG images available online (Fig. 3 and 4) and high-definition TIFFS are available as a 'virtual loan' to anyone who enquires. Additionally, the NHMs collections are now linked in comprehensive databases such World Register of Marine Species (WoRMS) (Fig. 5), the WoRMS Siboglinidae entries have also been updated through a separate project funded by the WoRMS LifeWatch grants and the International Network for the Scientific Investigation of Deep-sea Ecosystems (INDEEP) coordinated by the WoRMS Annelida Editor, Geoff Read and carried out at the NHM by Lenka Neal.

We hope our short communication celebrating the 100th year since the discovery of the Siboglinidae will help promote research and curation into these extraordinary animals.

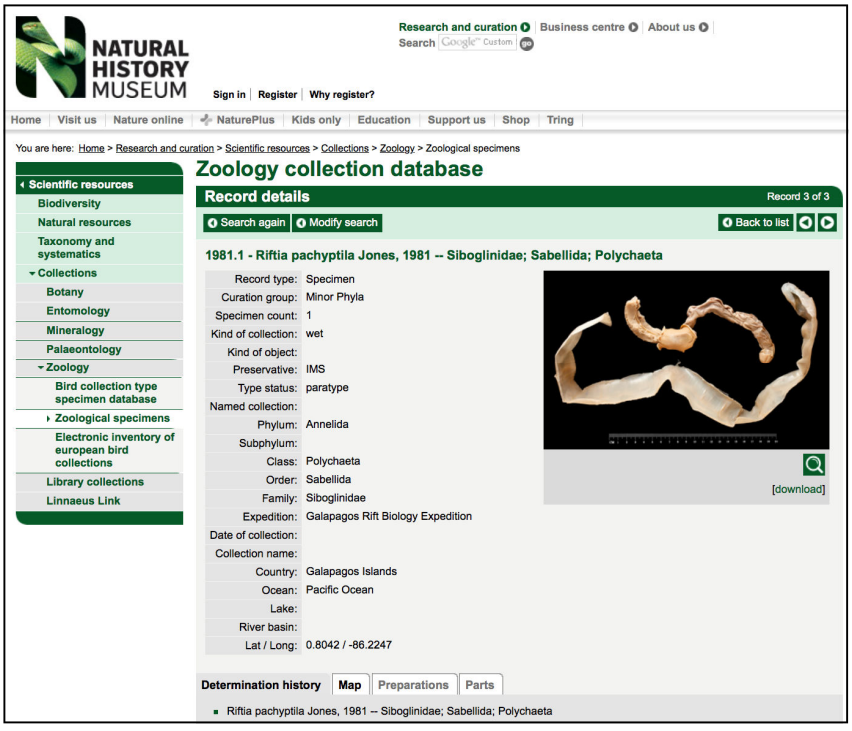


Fig 3. External access to the Natural History Museum collections data through http://www.nhm.ac.uk/research

Fig 5. External access to the Natural History Museum collections data through the World Register of Marine Species: http://www.marinespecies.org/

Acknowledgements

The authors would like to thank Dr. David George very much for his help and the use of the Diving image. Also thanks to the NHM data manager, Tim Conyers. Thank you to the anonymous reviewers.

References

Caullery, M. 1914. Sur les Siboglinidae, type nouveau d'invertebres recuillis par l'expedition du Siboga. *Comptes Renduz de l'Academie des Sciences*, Serie III **158.** pp. 2014-2017

Chambers, S. J., & Muir, A. I. 1997. *Polychaetes: British Chrysopetaloidea, Pisionoidea and Aphroditoidea.* Linnean Society of London and the Estuarine and Brackish-water Sciences Association.

De Beer, G. 1955. The Pogonophora. *Nature*. **176**. pp.888.

George, J. D. 1973. The pognophora and their affinities. *Microscopy*. **32**. pp.242-252

George, J. D. & Southward, E. C. 1973. A comparative study of the setae of Pognophora and Polychaetous Annelida. *Journal of the Marine Biological Association U.K.* **53**. pp.403-424

George, J. D. 1975. Observations on the pognophore, *Siboglinum fiordicum* Webb from Fanafjorden, Norway. *Underwater Association Report* 1975.

George, J. D. 1977. Ecology of the pogonophore *Siboglinum fiordicum* Webb, in a shallow-water fjord community. In: Biology of Benthic Organisms: *11th European Symposium on Marine Biology*. Pergamon Press.

Glover, A. G, *et al.* 2005. World-wide whale worms? A new species of Osedax from the shallow north Atlantic. *Proceedings of the Royal Society B.* **272**. pp.2587 2592.

Glover, A. G, *et al.* 2013. Bone-eating worms from the Ant arctic: the contrasting fate of whale and wood remains on the Southern Ocean seafloor. *Proceedings of the Royal Society B-Biological Sciences*. **280** DOI: http://dx.doi.org/10.1098/rspb.2013.1390

Hilario, A, *et al.* 2011. New perspectives on the ecology and evolution of siboglinid tubeworms. *PLoS ONE.* **6(2)** pp. e16309

Ivanov, A. V. 1963. *Pogonophora. Translated from the Russian and Edited by DB Carlisle. With additional material by EC Southward*. London: Academic Press Inc. 1963. p.479.

Johnston, G. 1865. *A catalogue of the British Non-Parastical Worms in the collection of the British Museum*. British Museum of Natural History London

Natural History Museum, 1920-1927. *Annelid Secion Annual Reports.* No. 0265/47

Paterson, G. L. J, *et al.* 1998. Hessler and Jumars (1974) revisited: abyssal polychaete assemblages from the Atlantic and Pacific. Deep-Sea Research Part I *Topical Studies in Oceanography.* **45**. pp.225-251.

Paterson, G. L. J, *et al.* 2009. A census of abyssal polychaetes. Deep-Sea Research Part I *Topical Studies in Oceanography.* **56.** pp.1739-1746.

Rouse, G. W., Goffredi, S. K., & Vrijenhoek, R. C. 2004. "*Osedax*: bone-eating marine worms with dwarf males." *Science.* **305.5684.** pp.668-671.

Southward, A. J., & Southward. E. C. 1958) Pogonophora from the Atlantic. *Nature*. **181**. pp.1607.

Pleijel, F., Dahlgren, T.G., & Rouse, G. W. 2009. Progress in systematics: from Siboglinidae to Pogonophora and Vestimentifera and back to Siboglinidae. *Comptes Rendus Biologies.* **332.** pp.140–148.

Uschakov, P. 1933. Eine neue Form aus der Familie Sabel lidae (Polychaeta). *Zoologischer Anzeiger.* **104.** (1933) pp. 205–208.

Van Dover, C. 2000. *The Ecology of Deep-Sea Hydrothermal Vents*. Princeton University Press

Webb, M. 1964. The posterior extremity of *Siboglinum fiordicum* (Pogonophora). *Sarsia*. **15**. pp.33-36.

APPENDIX 1

Siboglinidae listings at the NHM London

Registration Number	*Genus*	*Species*	*Type Status*
2013.484	*Osedax*	*antarcticus*	non-type
2013.483	*Osedax*	*antarcticus*	non-type
2013.482	*Osedax*	*antarcticus*	Voucher
2013.481	*Osedax*	*nordenskioeldi*	Voucher
2013.479-480	*Osedax*	*nordenskioeldi*	Paratypes
2013.478	*Osedax*	*nordenskioeldi*	Holotype
2013.477	*Osedax*	*rogersi*	Paratype
2013.476	*Osedax*	*rogersi*	Holotype
2013.475	*Osedax*	*crouchi*	Voucher
2013.474	*Osedax*	*crouchi*	Paratype
2013.473	*Osedax*	*crouchi*	Holotype
2013.437	*Osedax*	*antarcticus*	Paratype
2013.436	*Osedax*	*antarcticus*	Paratype
2013.435	*Osedax*	*antarcticus*	Holotype
2013.25	*Riftia*	*pachyptila*	non-type
2012.44-45	*Osedax*	*rubiplumus*	non-type
2012.42-43	*Osedax*	*frankpressi*	non-type
2012.104	*Osedax*	*rubiplumus*	non-type
2011.28	*Riftia*	*sp*	non-type
2010.233	*Lamellibrachia*	*anaximandri*	paratype
2010.232	*Lamellibrachia*	*anaximandri*	paratype
2010.231	*Lamellibrachia*	*anaximandri*	paratype
2010.232	*Lamellibrachia*	*anaximandri*	paratype
2010.233	*Lamellibrachia*	*anaximandri*	paratype
2011.28	*Riftia*	*sp*	non-type
2012.42-43	*Osedax*	*frankpressi*	non-type
2012.44-45	*Osedax*	*rubiplumus*	non-type
1960.10.1.1	*Zenkevitchiana*	*longissima*	non-type
1960.10.1.3	*Polybrachia*	*capillaris*	types
1962.9.24.1	*Siboglinum*	*lacteum*	type
1969.3.3.3	*Siboglinum*	*pusillum*	non-type
1969.3.3.4-5	*Siboglinum*	*pusillum*	non-type
1971.2.1.26	*Lamellibrachia*	*barhami*	paratype
1978.3.21.1	*Lamellisabella*	*denticulata*	paratype
1978.3.21.2	*Lamellisabella*	*denticulata*	paratype
1978.3.21.3	*Lamellisabella*	*denticulata*	non-type
2013.25	*Riftia*	*pachyptila*	non-type
2013.435	*Osedax*	*antarcticus*	holotype
2013.436	*Osedax*	*antarcticus*	paratype
2013.437	*Osedax*	*antarcticus*	paratype

Registration Number	Genus	Species	Type Status
2013.473	*Osedax*	*crouchi*	Holotype
2013.481	*Osedax*	*nordenskioeldi*	Voucher
2013.479-480	*Osedax*	*nordenskioeldi*	paratypes
2013.478	*Osedax*	*nordenskioeldi*	holotype
2013.476	*Osedax*	*rogersi*	holotype
2013.477	*Osedax*	*rogersi*	paratype
2013.475	*Osedax*	*crouchi*	voucher
2013.474	*Osedax*	*crouchi*	paratype
2013.482	*Osedax*	*antarcticus*	voucher
2013.483	*Osedax*	*antarcticus*	non-type
2013.484	*Osedax*	*antarcticus*	non-type
1978.3.21.3-5	*Lamellisabella*	*denticulata*	non-type
2005.239	*Osedax*	*mucofloris*	holotype
2005.240	*Osedax*	*mucofloris*	paratype
2005.241	*Osedax*	*mucofloris*	paratype
2012.104	*Osedax*	*rubiplumus*	non-type
2007.977	*Spirobrachia*	*tripeira*	holotype
1958.8.28.1	*Siboglinum*	*atlanticum*	syntype
1958.8.28.2-3	*Siboglinum*	*inermis*	syntypes
1960.10.1	*Polybrachia*	*capillaris*	syntype
1962.1.9.1	*Galathealinum*	*arcticum*	holotype
1963.5.2.1	*Siboglinum*	*holmei*	holotype
1963.5.2.2	*Siboglinum*	*holmei*	paratype
1963.5.2.3	*Siboglinum*	*holmei*	paratype
1969.3.3.1	*Siboglinum*	*vancouverensis*	holotype
1969.3.3.2	*Lamellisabella*	*coronata*	holotype
1978.1.13.1	*Unibrachium*	*colombianum*	paratype
1978.1.13.2-3	*Sclerolinum*	*minor*	paratypes
1978.1.13.4-7	*Sclerolinum*	*major*	paratypes
1978.1.13.8-15	*Sclerolinum*	*magdalenae*	paratypes
1978.1.13.16	*Oligobrachia*	*gracilis*	holotype
1978.1.13.17	*Oligobrachia*	*gracilis*	paratype
1978.1.13.18-20	*Oligobrachia*	*gracilis*	paratypes
1978.1.13.21-22	*Oligobrachia*	*gracilis*	paratypes
1978.1.13.23-27	*Oligobrachia*	*gracilis*	paratypes
1980.1-3	*Oligobrachia*	*hawaiiensis*	paratypes
1980.4	*Oligobrachia*	*hawaiiensis*	paratype
1980.5-8	*Siboglinum*	*ordinatum*	paratypes
1981.1	*Riftia*	*pachyptila*	paratype
1991.4	*Lamellibrachia*	*columna*	paratype
1996.1048	*Arcovestia*	*ivanovi*	holotype
1996.1049	*Arcovestia*	*ivanovi*	paratype
2001.6633	*Paraescarpia*	*echinospica*	paratype
1991.1-3	*Siphonobrachia*	*lauensis*	paratypes

Remedial conservation of a severely deteriorated 19th century bound herbarium

Magdalena Grenda

Warsaw Rising Museum, Ul. Grzybowska 79
00-844 Warsaw, Poland

Email: grenda.magdalena@gmail.com

Received: 20th Oct 2014
Accepted: 21st Dec 2014

Abstract

In 2012 the Rev. Krzysztof Kluk Museum of Agriculture in Ciechanowiec, Poland, sent their 19th century herbarium for conservation treatment. The condition of the object was so poor that it could not be subjected to any analysis or even digital documentation. The bound herbarium had broken covers, dismantled construction and weakened spongy paper support with a lot of tears and losses. The specimens were either seriously damaged, missing or under serious risk of destruction. Over a half of them had fallen off their places and could be found in the area of the spine, often mixed within pages. The owner wanted the object to be displayable and safe for handling. Close work between the conservators and ethnobotanist was required to ensure a full and complete understanding of the bound herbaria as a whole, but also the individual specimens. Sever treatment was undertaken including many typical paper conservation solutions and re-arrangement of puzzle-like assemblage of specimens based on interdisciplinary consultation. The description of the treatment is a pretext to consider the methodology and standards concerning the care and conservation of botanical material.

Keywords: Herbarium; Specimen; Remedial Conservation; Ethnobotany; Standard; Methodology; Biocultural Collections; Ethics; Ethnobotany

Introduction

This article describes issues concerning conservation treatment of a 19th century bound herbarium from the collection of the Rev. Krzysztof Kluk Museum of Agriculture in Ciechanowiec, Poland. The herbarium was not considered a scientific resource for taxonomists or ethnobotanists but rather a social history object illustrating the workshop of a 19th century pharmaceutist and the usage of medicinal plants. The methodological discussion and consequent conservation treatment aimed at preparing the historic object according to the needs of the owner with regard to possible future uses of the item were carried out to the correct conservation and ethical standards. Particular consideration regarded the applicability of paper conservation techniques to plant material and possible conflict between the contemporary theory of conservation and standards designed for the botanical material.

According to methodological procedure described by Appelbaum (2010), requiring definition and correlation of every concerned factor, the article describes the profile of the custodian, the treated object itself, the condition of the herbarium before treatment, methodological issues, definition of the goal of treatment, the course of treatment and conclusions.

Background to the Museum of Agriculture

The rev. Krzysztof Kluk Museum of Agriculture in Ciechanowiec, was founded in 1962, initiated by the Society of Ciechanowiec Aficionados. The institution is located in the historic park and palace of Starzeński family, dating from the mid-19th century. Consisting of eight departments devoted to Ethnography, Technology of Agriculture, Art and History, Rural Architecture, History of Plant Cultivation, Herbal Traditions, History of Farming and Veterinary Medicine the museum covers a large array of collections.

Grenda, M. 2015. Remedial conservation of a severely deteriorated 19th century bound herbarium. *Journal of Natural Science Collections*. **2.** pp. 54-59.

The Department of Herbal Traditions was created in 1984, resulting from the large collections from Reverend Krzysztof Kluk, the author of the first important Polish ethnobotanic study (Kluk 1786-1788; Luczaj & Szymañski 2007). It is responsible for caring for the garden growing medicinal plants as well as displays focusing on herbal traditions, partly presented on a permanent basis, the department also held collections. These collections not only include herbaria, but also the unique tools and instruments used to produce and store herbal medicines, pharmacy furniture and all that could create a herbalist workshop.

The object: a 19th century herbarium

The origin of the herbarium is unknown. The previous owner found it in the attic of his grandfathers' house and there was no further information about the collector or it's history. One of the watermarks allowed the bound volume to be dated to after 1816. There was one other mark on the front cover; written in contemporary handwriting the inscription "KLUK" (Fig. 1). It is unlikely to have belonged to the Reverend Krzysztof Kluk himself, as he died in 1796 and the paper support for the specimens was produced 20 years after his death. There was no any further indication that the specimens were collected by this famous ethnobotanist. It appears that somebody wanted either to assign the herbarium to reverend Krzysztof Kluk to make it more valuable by suggestion of his authorship, or to attribute it to the whole institution named after the reverend. It might have been also an act of thoughtless vandalism.

Almost all of the specimens in the herbarium had handwritten captions, though the accuracy and character of the captions were not homogenous. Some of the names were written in Polish, some in Latin, and there were many sheets missing any information. Some species were assigned to a taxonomic group while the other ones would be given a longer description concerning the traditional uses and side effects of the plant.

Condition of the item

The item was in very poor condition before treatment. The herbarium album has 50 unnumbered pages; originally there were 62 pages but twelve sheets must have been cut and only the rabbets remained in the last 3 folds. Although the total number of folds is 17, the number of the pages within one fold is not regular, varying from 3 to 5. On each page there are numbered handwritten names of the plants. The album was bound in half calfskin with corners, leather straps and block-printed paper, but the binding was so ruined that it did not function as a protection for the block of the album. The leather spine was missing, the covers were broken and only half the front cover remained.

The cardboard of the covers was stratified, showing fragmentarily a stack of handwritten notes used as a waste paper to form the boards. The sewing and threads were brittle and torn and the cover paper was heavily degraded, darkened, and weakened by heavy abrasion. Covered with stiff crust of animal glue folds were stiffened and broken. The paper sheets, made of greenish laid paper, were stained and discoloured. The staining was only partially concerned with the direct contact of plants and paper. The paper support was very dirty, spongy, with a lot of tears and losses. The losses were caused not only by abrasion of the edges, but were also the result of the pest activity (larvae holes). Numerous straps of a white laid paper remained on the pages, sometimes partially delaminating from the support, at times without accompanying specimen they were intended to hold. Most of the original colour of the paper faded.

The pressed plant specimens were in a different condition. According to the handwritten descriptions and brown stains in the paper support, that indicated former specimens' locations, there should be from 4 to 9 specimens on each page. Over a half of them had fallen off their places and could be found in the area of the spine, along with dead insects and the original straps of white laid paper that delaminated from the pages. During the treatment and

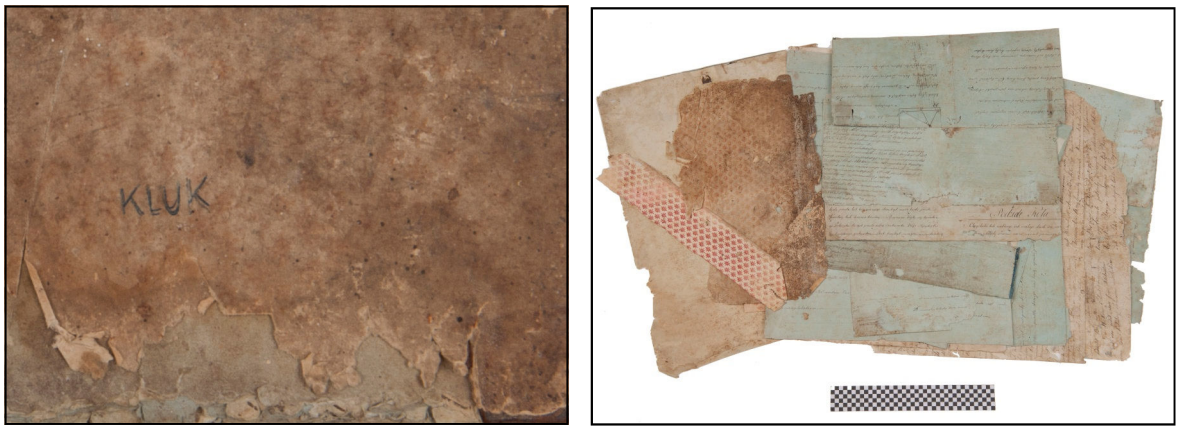


Fig. 1. The front of the bound herbarium (left), with the word 'KLUK' written. Right shows the poor condition of the loose pages.

ethnobotanic analysis the specimens turned out to be often disarrayed within pages. Dislocation and lack of stabilising support caused damages to brittle specimens, ranging from tiny cracks to breakages, losses or crushing. Less than half of specimens remained in their original position. A lot of specimens were missing.

Methodological issues of concern

According to the Standards in the Care of Botanical Collections (2014) any associated written data accompanying a specimen is as important as the specimen itself. A specimen with no data has no scientific value (but does potentially have other uses, such as educational, artistic, and general research). Data provides evidence of where the specimen was found, who found it and when it was collected, and several authors have stressed the importance of specimens with data (e.g. Bedford, 1999; Allaby, 2012; Salick, Konchar & Nesbit, 2014). Research must rely on defined and identifiable species that can be referred to, but how does it apply to items that do not contain complete information of the specimens collection and history? The inevitable question is: are these specimens without data condemned to be treated as a 'useless' for any serious research? Herbarium specimens have been used for research in numerous different areas, including, for example, anthropology, conservation and ecology to taxonomy, medicine and genetics (Magrez 2004; Crouch, *et al.,* 2014; Hart, Law & Jackson, 2014; Spooner, 2014). Herbaria can also be used as 'teaching collections' (Adams & Fritz, 2014), but this does not need a strict amount of data to qualify the item as 'valuable'.

Muñoz Viñas (2005) in his contemporary theory of conservation argues that neither conservation nor science is a clearly defined activity, though in relation to science, conservation aims at preserving the *true nature*, that relies mainly upon the material constituents. The 'ethno-historic pieces of evidence' are objects that work as historical evidence and form separate category of artefacts. However, any treatment is the matter of decisions that may affect the objects appearance and structure (Florian, Kronkright & Norton, 1990; Hill, 1999) and therefore is an act of interpretation (Muñoz Viñas, 2005; Appelbaum, 2010). The choice of sizing agents for paper or the other substances commonly introduced in paper conservation (e.g. deacidiying agents for acidic environments) as well as decisions to discard old mounts or elements of construction, may actually be a threat for sustainability (Muñoz Viñas, 2005).

The notion of sustainability is used here in the meaning of 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Staniforth, 2000, cited here after Muñoz Viñas, 2005). A mistake in choosing the values to be preserved or discarded may result in *fabrication* of an artefact that is rather a visualisation of a state considered an 'ideal state' or, in other words, how a certain kind of object should look like state. This sort of situation can happen even when it comes to the treatment of a scientific specimen, particularly when it is not acknowledged as precious and of significant value for the collection, or the collection becomes out of fashion (Appelbaum, 2010). As Appelbaum (2010) describes, 'there is nothing intrinsic to an object that puts it in category. *We* do that.' This does not mean that it's safer not to treat the object.

According to the AIC Code of Ethics (2014), conservators should 'select methods and materials that, to the best of current knowledge, do not adversely affect cultural property or its future examination, scientific investigation, treatment, or function.' The Code underlines the functioning of the object at the same level as examination and scientific investigation; if the object is already in its autocatalytic phase, in which each step in the aging process promotes further aging (Appelbaum, 2010), the treatment may turn out to be necessary and inevitable. The future significance of the object can be unpredictable, thus the discussion about treatment should focus on the proper assessment of values and anticipated use of the item in the collection, keeping in mind the probable shift in valuing the object in the future. The shift of value may concern using the herbarium for DNA analysis or change of significance of the item for natural history collections in general. Possible changes must be taken into consideration during conservation treatment planning, which involves the choice of proper conservation materials that will not affect the qualities of the treated material.

The herbarium from Ciechanowiec needed to be assessed and treated according to the procedures raised above. The Museum of Agriculture is focused on the education and promotion of the traditional knowledge and thus in preserving the original values concerning agriculture and related fields. The diversified nature of the museum and its collections requires flexible planning, as there are a variety of different objects and this herbarium is only one of two in the entire collections. The specimens are accompanied with descriptions, but of different level and precision, and lack the completeness required for a typical scientific source. The data does not indicate were the specimen was collected, but some contain detailed description of the medicinal use and effects of usage, what places them among the group of exceptional cases of ethnobotanical documents (Bedford, 1999; Nesbitt, 2014). This small collection is not generally qualified as "scientific herbarium" and the poor condition of the item precluded safe handling or analysis, and it was decided that the treatment would not change the appearance of the object. There could be a conflict between choosing methods appropriate for the conservation of the support and the treatment suitable for the plant specimens; both required treatment because of disintegration of the object

and both seemed to be equally essential and valuable for the character of the object as a whole.

Defining the goal and plan of treatment
The herbarium was aimed to be treated for substantial analysis and exhibition. The conflict between the desired function and the item's condition before treatment resulted in decisions for treatment as follows:

1. The object should become usable; the condition before treatment did not allow safe handling or safe storage. The object was highly disintegrated, resulting in numerous loose elements, most of which were damaged. The damage was at all levels, from the outermost element of the binding to the innermost parts of the specimens and paper support.

2. The object should be made suitable for display. The weakened condition of the binding and paper support made it impossible to display and there was the additional risk of exposing the herbarium to any light level. The loosened structure posed the risk of further loss of item's elements and any information.

3. As much as it is possible the object should be made safe to handle for information and for display as part of an exhibition. All parts of the object should be reintegrated and stabilised by full conservation treatment including remounting of the loose specimens. The re-introduction of the specimens would actually enable the analysis of the herbarium. It required that the conservator conducted a preliminary analysis and identified as many species as possible to remount them properly. The museum doesn't have a conservation studio to work directly with a conservator, so consultation with ethnobotanist was required to provide reliable information during re-matching the specimens to their original location. All information that could not be re-used in the object was to be separated and treated as an attachment to the documentation.

Treatment
The object was photographed showing general condition as well as in it's original page-by-page sequence. Photographing each page was necessary to enable later matching of dislocated specimens. The pH of the paper was measured demonstrating it was fairly neutral, varying from 5 to 6.3 (all pH measurements were done using Mettler Toledo SevenEasy pH-meter, calibrated with buffers of 4.01, 7 and 9.21 pH value).

The pages were numbered with a pencil to be treated individually. The sewing in the binding was cut and loose specimens and paper straps and from each page were removed and put into a separate envelope, which was numbered with the corresponding page number. The tiny crushed specimen particles, dust and dead insects were discarded due to the impossibility of matching them to their original host. Then the page was separated from the block. With all loose elements taken out, the pages and covers were dry cleaned with soft brush, latex sponge, scalpel, and soft rubbers, with great care due to the brittleness of the specimens that remained on the pages (see other reports on methods and issues of dry cleaning of herbaria Margez, 2004; Menei, 2005; Dauwalder, 2013). With plant specimens attached to some sheets, the whole sheet could not be cleaned, but it was possible to execute some local treatment. Brown staining in the folds' spines and on the edges of the sheets, which made the paper more brittle, was reduced with local washing with deionised water. The other kind of discolouration that was a result of direct contact of specimens and paper, was not considered as a sign of degradation of the support that should be altered; it was regarded as a kind of documentation of specimen, particularly in cases where specimen themselves were missing and the contour or characteristic shape of staining could help in matching the loose specimens.

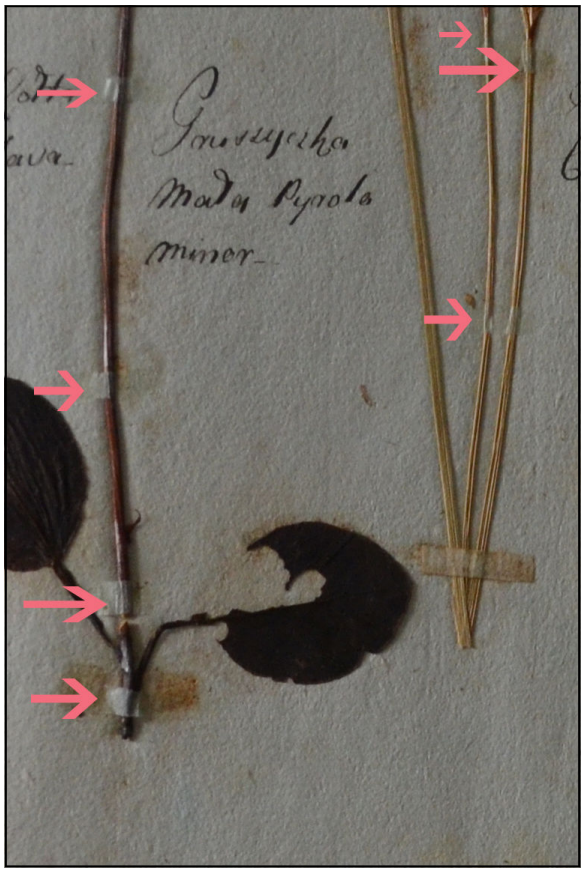
Paper was deacidified with Bookkeeper spray from the back; it was not used on the front of the pages due to the potential risk of it reacting with natural dyes. Deacidification is common and popular practice in paper conservation (Giorgi, 2013), the possible effect of deacidifying agents used for conservation purposes on plant specimens is still not known. The paper support was reinforced with 2% methyl cellulose from the back, which prevented the specimens that were still attached to the pages from direct contact with the sizing agent. To minimize the number of the 'elevated humidity' stages of the treatment, the losses in the paper were infilled and tears were mended straight after introducing the methyl cellulose. The tears were supported with 9gsm Japanese tissue and the losses were infilled with 32gsm Japanese kozo paper, dyed with hellion dye to the greenish colour matching the colour of the original paper (Fig. 2). The paper for the infills was dyed prior to application. Japanese papers were adhered with rice starch paste with addition of antiseptic Aseptina M. After reinforcement and infilling the losses the pages were flattened under felt and weights. Using felt provided safe pressure for the plant specimens. The process of paper reinforcement was successful and did not damage the plants, although exposed the specimens to elevated humidity. The shifts in RH might accelerate deterioration of specimens (Florian, Kronkright, & Norton, 1990). In this case the paper support was extremely spongy and probably suffered from previous microbiological attack.

The other method to reinforce the paper that might have been considered would be removal of all specimens, and remounting them after paper conservation treatment. Although the risk of the plant

being damaged would be reduced, it would mean temporary total disintegration of the object that was already a composite of numerous loose elements. The decision to conduct the treatment without removing the plants that remained in their original location was a difficult compromise between the willing to keep as much original information together as possible and the safety of the separate elements of the herbarium. There was no noticeable difference in the condition of specimens after the process of reinforcement and drying. The pH of the paper after the process of paper conservation treatment raised to average of 8. The value of pH was slightly higher on the backsides due to the fact that Bookkeeper tends to have limited ability of penetration (Zumbühl & Wuelfert, 2001).

The covers were dry cleaned and washed in deionised water. During the washing a bundle of the handwritten papers used as a waste paper for the cardboard was retrieved. The papers were cleaned from the glue residues and then deacidified with Bookkeeper spray. The sheets were sized with 2% methyl cellulose. Splitting the papers of the boards resulted in retrieving two pieces of the block-printed cover paper that was not degraded. The pieces provided the basis for the reconstruction of the paper for the new binding. The original leather fragments were cleaned with a Maroquin balm.

The next phase concerned reintegration of the herbarium's content. Firstly, the conservator attempted to match the specimens found on particular page to the captions on the same page. If the specimen didn't match to any location, the conservator searched for the right place on the other pages. Using the names given to plants, loose specimens were matched by identifying them. All loose specimens were photographed and sent to the museums ehthnobotanist to check which assisted in 90% of the specimens matched. A few descriptions proved to be insufficient or mistaken emphasising the caution needed. Only plant-to-staining matches that were easily matched were mounted onto the original place, any ambiguous matches were treated as attachments and were put in a separate acid-free envelope.



The approved specimens were remounted onto pages with 9 gsm Japanese tissue dyed to the greenish tone, adhered with rice starch paste with addition of antiseptic Aseptina M. The starch paste is used for reattachment for its good adhesion properties and reversibility (Hill, 1999; Margez, 2004; Menei, 2005). If there were original straps in the place of missing specimens, they were used to attach the plants to the pages. If no original straps were provided, specimens were attached with the straps of the 9 gsm Japanese tissue, which was also used to line the original straps that remained partially. In some cases, conservator added some additional Japanese tissue straps even if all the original points of adhesion remained (Fig 3). The decision depended on the behaviour of the specimen when turning the pages: if it tended to protrude and risk in breaking, it was secured by another point of adhesion. At the final stage of treatment, the block was resewn and bound in a new binding, reconstructed basing on the remains of the original binding. The paper was reconstructed in the computer image processing software and printed in a high quality laser printer office.

The conservator made a customised protective acid -free box, construction of which enabled to house both the object and all original attachments, stored in buffered paper envelopes. The owner was provided guidelines for the environmental conditions for storage and exhibition, with suggested temperature 16-18^{o}C and RH 50% ± 5, according to the usual standards for paper and ethnographic collections (e.g. Bedford, 1999; Timbrook, 2014). The conservator recommended that the page exposed to light at the exhibition should be changed once a month. Currently the herbarium successfully plays an integral role of the museum displays.

Fig. 2. The arrows show the points of adhesion of the dyed Japanese tissue.

Conclusions

The album was reinforced and secured at different levels which allowed it to be used again: it was prepared for safe handling and a protective box made of acid-free materials provided stable and easy storage both for the album and all other original elements of the item. The conservator's analysis and documentation shed some light on the object's history and gave a basis for further substantial research. Thus a new resource for ethnobotanic studies appeared in the collection what would not be possible without the preliminary ethnobotanic analysis. Unaccompanied by interdisciplinary cooperation, the treatment would not be complete. Documentation of every stage of treatment proved to be essential as it enabled tracking of the specimens changes during the treatment. Should there be any need to make future changes, it is easy to remove a specimen if required.

The conservation treatment described here is an example of a complicated, and perhaps disputable, intervention. The look of the herbarium changed dramatically. There are few published case studies on working on bound herbaria (e.g. Magrez, 2004; Menei, 2005; Dauwalder, 2013) so promoting the work will enhance the discussion and awareness of the problems concerning the care and conservation of plant-based materials.

Discussion about the standards, raised during the Clothworker's Standards workshop at the 29th Annual Meeting for the Society for the Preservation of Natural History Collections in Cardiff, proved there are still areas and subjects to be revised and discussed, e.g. standards for exposure conditions and stratification of the standard (depending on funds and size of an institution). As a conservator, the author would add that there is a need for further research on the relations between in conservation, mostly concerning paper conservation field, and conservation of plant-based materials. Relations understood both as the impact of technical materials and methods used during the treatment, and the possible influence of the contemporary theory of conservation on the decision making when it comes to the treatment of herbaria or other biocultural collections. The methodological background and treatment solutions should be always correlated with the needs of the owner, including any possible future uses of the herbarium. Difficult as it may seem to the conservator, the treatment should be coherent with the nature and the structure of the object down to the molecular level, but this also needs a further research.

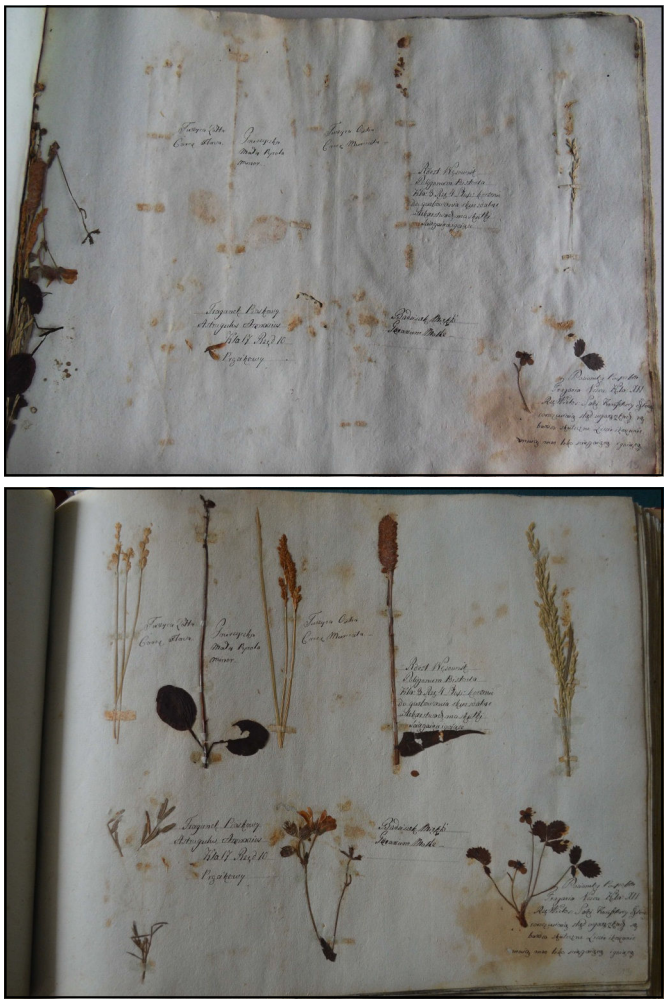


Fig. 3. (Top) A sheet from the herbaria with the loose specimens and dirt covered paper. Note the loose specimens have accumulated towards the centre of the album.
(Bottom) The same sheet after conservation. Where possible specimen have been reattached to their original places.

Acknowledgements
I am grateful to the rev. Krzysztof Kluk Museum of Agriculture and museum's director, Dorota Lapiak, for involving me in the project of herbarium conservation. I would like to thank particularly Dorota Gnatowska, the curator of the Herbal Traditions Department, for her kindness in cooperation during the process of conservation treatment and to Artur Warchala for documenting the item at the exhibition. I would also like to thank Prof. Lukasz Luczaj for ethnobotanist consultation, which enabled completing the treatment and fascinating investigation, and Robert Danieluk for basic documentation of the herbarium. I am extremely grateful to the hard work of the anonymous reviewers who checked and edited this paper.

References

Adams, C. T. 2014 Chapter 24 Using collections for edu cation, in Salick J, Konchaw K., Nesbitt M. (eds), *Curating Biocultural Collection. A handbook*, Kew: Kew Publishing 2014.

AIC American Institute for Conservation of Historic & Ar tistic Works. 2014. *Code of Ethics* (online) Available: http://www.conservation-us.org/about-us/core-documents/code-of-ethics#.VAiGurzV8R4 [accessed 3 September 2014]

Aiona, K., *et al.,* 2007. Ethnobotany, the science of surviv al: a declaration from Kaua'i, *Economic Botany* **61 (1).** pp.1-2.

Allaby M. (ed.) (2012) *Oxford Dictionary of Plant Scienc es*, Oxford: Oxford University Press

Appelbaum, B. 2014. *Conservation Treatment Methodolo gy*, Lexington: KY

Bedford, D. J. 1999. Chapter 3 Vascular plants, in: Carter, D. & Walker, A. (eds), *Care and Conservation of Natural History Collections*, Oxford: Butterwoth Heinemann.

Crouch, N. R., *et al.* 2014. Chapter 19 Multicultural per spectives on biocultural collections, in Salick J, Konchaw K., Nesbitt M. (eds), *Curating Biocultural Collection. A handbook*, Kew: Kew Publishing 2014

Dauwalder, L. 2013, Felix Platter's Herbarium: The Preservation of a Historical 'Bound Herbarium', *Journal of Paper Conservation.* **14(3).** pp.26-32

Florian, M. E., Kronkright, D. P., & Norton, R. E. 1990. *The conservation of artifacts made from plant materials*, Getty Trust Publications : Getty Conservation Institute

Giorgi, R. 2013. Chapter 15 Inorganic Nanomaterials for the Deacidification of Paper, in Baglioni P., Che lazzi D., O'Birien P. (eds) *Nanoscience in the Conservation of Works of Art*, Cambridge: Royal Society of Chemistry 2013

Hill, G. 1999. Chapter 10 Paper Conservation and the Herbarium, in: Metsger D. A., Byers S.C. (eds), *Managing the Modern Herbarium. An inter-disciplinary approach*, Washington DC: Society for the Preservation of Natural History Collections

Kluk, K., (1786-1788) *Dykcjonarz roślinny, w którym podług układu Linneusza są opisane rośliny nie tylko krajowe, dzikie, pożyteczne albo szkodliwe: na roli, w ogrodach, oranżeriach utrzymywane: ale oraz i cudzoziemskie, które by w kraju pożyteczne być mogły albo z których mamy lekarstwa,korzenie, farby etc., albo które jakową nadzwyczajność w sobie mają: ich zdatności lekarskie, ekonomiczne, dla ludzi, koni, bydła, owiec, pszczół etc.*, Warszawa : Drukarnia Xięży Piarów 1786 (vol.1), 1787 (vol. 2), 1788 (vol.3)

Luczaj L., & Szymañski W. M. 2007. Wild vascular plants gathered for consumption in the P o l i s h countryside: a review, Journal of Eth nobiology a n d E t h n o m e d i c i n e 2 0 0 7, 3 : 1 7 (online) Available: doi:10.1186/1746-4269-3-17 [accessed 3 September 2014]

Margez, M. 2004. *L'herbier Haller du Muséum na tional d'Histoire naturelle : un objet d'intérêt historique et scientifique*, Paris: Institut na tional du patrimoine Deìpartement des res taurateurs Menei E. (2005) *Conservation et restauration d'herbiers : un cas exemplaire à l a Bibliothèque de l'Institut de France* (online) Avail able: http://www.livre- f r a n c h e c o m t e . c o m / ? i d=180 [accessed 3 September 2014]

Muñoz Viñas. S. 2005. (edition 2011) *Contemporary theory of conservation*, Oxon, New York: Routledge

Nesbitt, M. 2014. Chapter 22 Use of herbarium specmens in ethnobotany, in Salick, J, Konchaw, K., Nesbitt, M. (eds), *Curating Biocultural Collection. A hand book*, Kew: Kew Publishing 2014

Salick, J., Konchar, K., & Nesbitt, M. (2014) Chapter 1 Biocultural collections: needs, ethics and goals, in Salick, J, Konchaw, K., Nesbitt, M. (eds), *Curating Biocultural Collection. A handbook*, Kew: Kew Publishing 2014

Spooner, D. M. 2014. Chapter 21 Research using biocultural collections, in Salick J, Konchaw K., Nesbitt M. (eds), *Curating Biocultural Collection. A handbook*, Kew: Kew Publish ing 2014

Spooner, D. M., & Ruess H. 2014. Chapter 7 Curat ing DNA specimens, in Salick J, Konchaw K., Nesbitt M. (eds),*Curating Biocultural Collection. A handbook*, Kew: Kew Publish ing 2014 *Standards in the Care of Botanical Material*, Clothworkers and Standards (2 0 1 4) (online) Available: http:// conser v a tion.myspecies.info/node/35 [accessed 3 September 2014]

Staniforth, S. 2000. Conservation: signifikance, relevance and sustainability, in: *IIC Bulletin* 2000 (6): 3-8

Timbrook, J. 2014. Chapter 2 Curating ethnographic specimens, Salick J, Konchaw K., Nesbitt M. (eds), *Curating Biocultural Collection. A handbook*, Kew: Kew Publishing 2014

Zumbühl, S., & Wuelfert, S. 2001. Chemical aspects of the bookkeeper deacidification of cellulo sic materials: the influence of surfactants in *Studies in Conservation*, Volume 46 (2001), p.181-195 .

NatSCA AGM Minutes
12.00 hours, Thursday 26th June 2014

Victor Slavi suite, Wales Millennium Centre, Cardiff Bay

Apologies for absence were received from Tony Irwin and Simon Moore

Minutes of AGM Thursday 28th February, 2013, held at the Yorkshire Museum, as published in *Journal of Natural Science Collections* **1:** 66-71. These were signed as a correct record of that meeting.

Matters arising from AGM minutes. No matters arising.

Update on Projects: HLF, ACE & NH Near You

HLF curatorial trainees in Natural Science, David Gelsthorpe.

We are now entering the final year of the four year project, with trainees in Leeds and Manchester recently finishing their traineeships. 2014 sees three natural science trainees in Leeds, Manchester and Birmingham. Thanks to all those staff who have supported the project with placements, mentoring and support.

Before the AGM during our NatSCA open session, Paolo Viscardi demonstrated our new web page map for plotting 'Natural Science Collections near you'.

Chairman's Report: Clare Brown

Last year's "View from the Chair" opened with some bleak paragraphs about how natural science collections and their personnel were weathering many years of funding cuts, job removal and staffing restructures. I finished by saying that NatSCA is doing what it can to help our sector and hopes to do more. Although the climate we find ourselves in has changed very little – staff cuts and budget removal still hang over us all - I am delighted to report that this year, NatSCA have being doing A LOT more.

A great deal of our activity can be attributed to Arts Council England (ACE) and their backing of museum Subject Specialist Networks (SSNs) and natural science collections in England. We are very grateful to ACE for their continued support and are look forward to working with them in the future.

NatSCA's two recent ACE-funded projects have both had important and tangible results: the first, an unbiased survey of museum visitors on the popularity of museum galleries, had many interesting findings. The headline, though, must be that visitors' "most favourite" type of gallery in a mix-discipline museum was natural science (41%), followed by art (30%) and then live animals (25%). This piece of research serves as a glowing endorsement of natural sciences' popularity with the general public and should feature in the considerations of any museum management thinking of cutting natural science collections or staff.

The second project has given us the opportunity to employ two NatSCA 'project co-ordinators' on short-term contracts from October 2013. Justine Aw and Russell Dornan have been working on developing how NatSCA runs and installing systems and strategies for improving all of our activity. A great deal of the rest of this report is a reflection of this work.

Our website (natsca.org) is now looking more professional and, with up to date information on NatSCA and natural science collections in general, it is now an important resource for the sector. A fantastic addition this year, for example, has been the uploading of a complete copy of Carter, D. & Walker, A. K. (1999). Care and Conservation of Natural History Collections. Oxford: Butterworth Heinemann. I would also encourage members to populate the "Natural History Near You" map on the website. This is a great resource for tracking down natural science collections in the UK. We have popular Facebook, twitter and Flickr pages and have begun the process of making interacting with NatSCA online far easier with workshop bookings now via Eventbrite and payment using PayPal. This year saw the first edition of the Journal of Natural Science Collections as well as an upsurge of postings on our blog.

As in previous years, NatSCA has had the pleasure of contributing to the natural science curator traineeships under the HLF 'Skills for the Future' programme. Three trainees are currently learning the ropes at Manchester, Birmingham and Leeds and we wish them, and all previous trainees, the best of luck in their future careers.

We were delighted to welcome Prof. Alice Roberts and Prof. Iain Stewart as NatSCA patrons this year. It is great that they are willing to lend their considerable authority to our cause. We are also very pleased to be able to sign a Memorandum of Understanding with both SPNHC and GCG this year and look forward to taking this on.

NatSCA awarded two institutions money from the "Bill Pettit Memorial Award" this year. £750 each to the National Oceanography Centre in Southampton, for work on the Discovery collections they hold, and to The Grant Museum in London for work on the only articulated Quagga skeleton in the UK. We do not have the funds to make an Award next year but hope to resurrect it soon. NatSCA continues to support its membership through bursaries.

NatSCA was represented at this year's national Museums Association Conference in Liverpool as part of a panel discussing the value of natural science collections and their curators for engaging with contemporary environmental sustainability agendas.

NatSCA continues to support natural science collections at risk and keeps a weather-eye out for any museums that might be so. We contact institutions where necessary and continually monitor any situations of this nature.

We have been making some progress with the Home Office on the price of drugs licenses for museums. Hopefully we will have more to report on this in the coming year.

We ran one workshop this year, on the care of entomology collections at the Natural History Museum in London. The coming year's programme features: "Taxidermy: Creativity, Curation, Context and Care" in London on 18th July, a workshop on geological hazards (with GCG) in Oxford on 17th October, an identification of osseous and keratinous materials workshop in Leeds on 29th January 2015, a caring for botanical collections workshop in Liverpool in spring 2015 and a seminar on the conservation of taxidermy in Preston on 1st April 2015.

I would like to thank Simon Moore, Kate Andrew, Nicola Newton, David Notton, Claire Mellish, Tony Irwin and Beulah Garner, who are stepping down from the committee in 2014, for all their hard work for NatSCA over the years. On a personal note, I have spent three very happy years chairing NatSCA, I am delighted to be remaining on the committee and I wish the next incumbent every success in the role.

Lastly I would like to thank the team in Cardiff for their excellent hospitality this year and compliment them on a wonderful 2015 conference.

6. Secretary's Report, Cardiff, 26th June 2014:
Due to the cost of committee attending committee meetings around the country and due to the increased communication between committee members by email, twitter, blogging etc, we have decided to shrink the number of official committee members initially by natural wastage. We may bring an item to the next AGM to officially do this. We will ask for volunteers to help with committee business when required.

	Cardiff Museum 14/6/2013	Manchester Museum 18/10/2013	NHM, 6/2/2014	Cardiff 25/6/2014
Kate Andrew	⊘	⊘	⊘	✔
Jack Ashby	✔	✔	⊘	✔
Clare Brown	✔	✔	✔	✔
Paul Brown	✔	✔	✔	✔
Jan Freedman	⊘	⊘	⊘	✔
Beulah Gardner	✔	✔	✔	✔
David Gelsthorpe	✔	✔	✔	✔
Tony Irwin	⊘	⊘	⊘	⊘
Miranda Lowe	✔	✔	✔	✔
Claire Mellish	⊘	⊘	⊘	✔
Simon Moore	✔	⊘	✔	✔
Holly Morgenroth	✔	✔	✔	✔
Nicola Newton	⊘	✔	⊘	⊘
David Notton	⊘	⊘	✔	⊘
Roberto Portela Migues	⊘	✔	✔	✔
Vicky Purewal	✔	✔	✔	✔
Maggie Reilly	⊘	✔	✔	✔
Emma Bernard	✔	✔	✔	✔
Paolo Viscardi	✔	✔	✔	✔
Donna Young	✔	✔	✔	✔

7. Treasurer's Report: Holly Morgenroth

NatSCA Accounts
Income and Expenditure
Year End January 2014

Income			2013-14	2012-13
Institutional Subscriptions				
	Previous Years	30.00		60.00
	Current Year	1,379.82		1,230.00
	Future Years	135.00		90.00
			1,544.82	1,380.00
Personal Subscriptions				
	Previous Years	105.00		30.00
	Current Year	2,405.63		2,168.80
	Future Years	176.57		30.00
			2,687.20	2,228.80
Workshop Income				
	Herbarium I 2012	-		210.00
	Herbarium II 2012	120.00		325.00
	Law 2013	940.00		70.00
	Entomology 2013	306.00		-
			1,366.00	605.00
Conference Income				
	2011	-		435.00
	2012	182.00		5,713.00
	2013	6,630.00		810.00
			6,812.00	6,958.00
Grant Income				
	Audience Survey	10,000.00		-
	NIP	7,500.00		-
			17,500.00	
Other				
	Error	-		6.00
	Interest	9.16		10.99
			9.16	16.99
TOTAL INCOME			**29,919.18**	**11,188.79**

Expenditure			2013-14	2012-13
Running costs				
	Committee Expenses	1,958.99		980.53
	Insurance	864.94		860.70
	Postage	40.80		19.68
	Bank Charges	14.00		-
	Data Protection	35.00		35.00
			2,913.73	1,895.91
Events				
	Conference 2012	-		4,730.80
	Conference 2013	6,180.70		
	Workshops	934.94		423.37
			7,115.64	5,154.17
Publications & Information Provision				
	Journal print & postage	1,834.40		2,914.48
	Icon Leaflets	300.00		-
	Website	300.00		-
	Digitisation Cater & Walker	-		95.40
			2,434.40	3,009.88
Projects				
	Audience Survey	11,970.00		-
	NIP	3,841.80		-
	Bill Pettit Fund	1,838.15		-
			17,649.95	
Other				
	Recruitment Expenses	95.30		
	NBN Trust Sub	30.00		30.00
	HLF Trainee	-		750.00
	Fluid course bursary	-		100.00
			125.30	880.00
TOTAL EXPENDITURE			**30,239.02**	10,939.96

Excess Expenditure over Income	**-319.84**

Cash Flow Statement					
	01.02.2013	Current a/c	4511.17		
		Deposit a/c	16367.27		
				20878.44	
	31.01.2014	Current a/c	4182.17		
		Deposit a/c	16376.43		
				20558.60	
	Net Outflow				319.84

This report and summary accounts are for the period February 1st 2013 to January 30th 2014. Income and expenditure for 2013-14 is shown in the left hand column and 2012-13 in the right hand column for comparison.
SUBSCRIPTIONS

Attention is drawn to the increase in subscription income. Personal and institutional memberships are up by around 10% compared to 2012-13. Although subscriptions do not cover all our operational costs, they are vital to the wellbeing of the Association. We appreciate the support of all our personal and institutional members.

MEETING INCOME
Income from the 2013 conference is roughly the same as that from 2012. However, workshop income increased significantly, largely due to the success of the Natural History Collections and the Law workshop which was very well attended. It should be noted that income received for these events after January 30th 2014 has not been included in these accounts.

INCOME FROM ARTS COUNCIL ENGLAND (ACE)

- NatSCA has been extremely fortunate to be successful with not one, but two, funding bids to ACE. Audience Survey: £10,000 from ACE + £2,000 from NatSCA reserves
- Network Improvement Project (NIP): £7,500 from ACE with a further £7,500 to follow in the 2014-15 financial year.

Most of the grant income for both projects was received in the 2013-14 financial year and it is predominantly due to these projects that our income and expenditure have been much higher than previous years.

EXPENDITURE
NatSCA has continued to support its individual members through bursaries for conferences and workshops (accounted for in the conference and workshop expenses) as well as supporting institutional members through the Bill Pettit Memorial Fund award.

Committee expenses showed the most significant increase in expenditure. Such expenses include travel to committee meetings and committee members' attendance at external meetings to represent NatSCA and advocate for natural science collections and those responsible for them. In response to this increase we have explored the most cost effective locations in which to hold our meetings and as part of the NIP project we have addressed committee roles which is helping us reshape the way we operate and the costs involved.

Overall, our expenditure exceeded income by £319.84
Proposed: Erica McAlister Seconded: Anthony Roach

8. Membership secretary's Report:
Maggie Reilly

For the membership year 01.02.2013 – 31st January 2014 we have the following membership breakdown:

179 paid up personal members
54 paid up institutional
Total paid up membership = 233

213 UK based therefore 20 overseas.
These figures include 31 new or returning members and membership has remained roughly constant at around the 230 – 250 mark for several years.

The free of charge (FOC) mailings were reviewed and we continue to send out 12 such mailings to copyright libraries and relevant cognate bodies and organisations. This year we add our two new patrons to the list.

There have been a number of changes in NatSCA opeartaions this year (described elsewhere in the AGM report) this year but the biggest change for membership purposes has been the introduction of Paypal as a means to pay your sub. Sincere thanks are recorded to Justine Aw, Russell Dornan and Paolo Viscardi for enabling all of that – considerable technical knowhow was required!

In addition, we are now holding membership data in a secure on-line database set up by Justine- this allows for easier data sharing between the treasurer, myself and others on committee.

Finally we have a generic google mail address for membership queries ie membership @natsca.org and this attracts a fair number of queries. Apologies for initial delays in dealing with such queries but we hope it is now working more smoothly. Encouragingly for the 2014 membership year, there are 225 members currently paid up (which is good for this stage in the year! Around 50 people, most new members have used the paypal facility so it is working well and clearly is attracting memberships.

Subs increase
Considering recent treasurer's reports on income and expenditure, levels of reserve income and the significant increased levels of NatSCA activities, the reluctant conclusion has been reached that we will need to increase subscription levels from 2015 in order to maintain or increase activities. It is proposed to raise personal subs to £20 (but retain a reduced rate for unwaged members) and institutional subs to £40 per annum. This will be put to the AGM in June. Subs had been maintained at very modest levels for many years now but the accounts reveal that basic income no longer covers basic costs of journal production and distribution, bursary and small grant awards and committee running expenses. All other means to increase income e.g. increasing membership, securing grants, training courses will also be considered and pursued.

9. Editorial & Website Report:
Jan Freedman & Paolo Viscardi

We are happy to welcome the new Journal for NatSCA, the Journal of Natural Science Collections. Thank you to Paolo, Russell and Justine for all their help on the formatting and design.

The new Journal is fully peer reviewed. Each article is reviewed by two external specialists. Reviewing the articles means that they are of a high standard and all the information is correct. Reviewers return the articles with comments and recommendations for changes and advise if it is suitable for the Journal. We have rejected 3 articles.

The Journal is aimed at you, the membership. We want the Journal to be as useful as possible and the first issue is full of interesting articles on a variety of topics, including conservation, collections reviews, working with volunteers and engaging with audiences.

All the back issues of all old NatSCA, and BCG publications are available on the new NatSCA website (www.natsca.org/publications). This archive is full of interesting and useful articles useful to the curator today. The archive is searchable, and the publications free to access.

The new Journal will be published once a year in December. The following December after the print date, the issue will be available online and be free to access.

The Journal is for you, so if you would like to see a subject written about, please do contact the editor (editor@natsca.org).

10. Natural Science Conservation (& Institute of Conservation) Report:
Vicky Purewal
Paul Brown reported that the three leaflets on the Care and Conservation of Zoological, Botanical and Geological Specimens have been produced with thanks to Simon Moore, Kate Andrew and Donna Young and printed jointly with The Institute of Conservation (UK).
It was also reported the success of the Conservation of Hair Conference hosted at the Horniman Museum and Gardens on the 19th of June 2014

11. The Seminar Programme
n/a

Election of Chair, secretary & ordinary members of NatSCA committee

Below are the nominees for NatSCA committee posts to serve from 2014 to 2016 **except the Chair and Secretary, who will serve from 2014 to 2017,** which have reached the secretary.

The membership secretary has checked to see that those proposed, those proposing and those seconding are all present members of NatSCA.

1. Chair 2014-2017 Paolo Viscardi Horniman Museum
Proposed: David Geltsthorpe seconded: Donna Young
2. Secretary 2014-2017 Roberto Portela Miguez NHM, London
Proposed: Anthony Roach seconded: Ben Rowson
3. Editor 2014-2016 Jan Freedman Plymouth Museum
Proposed: Jennifer Gallighan seconded: Andrew Haycock
4. Membership 2014-2016 Maggie Reilly Hunterian, Glasgow
Proposed: Geoff Hancock seconded: Cathie Way
5. OM 2014-2016 Donna Young Liverpool Museum
Proposed: Wendy Atkinson seconded: Henry McGhie
6. OM 2014-2016 Clare Brown Leeds Museum
Proposed: Glenn Roadley seconded: Jack Ashby
7. OM 2014-2016 Paul A, Brown NHM London
Proposed: Theresa Howard seconded: Erica McAlister

As there are no contested posts, no election is required. If there are no objections to the candidates, can we accept and elect the listed people en block onto committee to serve for three years for the treasurer and two years for other committee members.

This was proposed by Rob Huxley and seconded by Sue Ryder and was carried with no abstentions.

Already in post
8. Treasurer 2013-16 Holly Morgenroth Exeter Museum
9. OM 2013-2015 Jack Ashby Grant Museum, UCL
10. OM 2013-2015 Miranda Lowe NHM, London
Conservation 2013-2015 Vicki Purewal NMGW, Cardiff
11. OM 2013-2015 David GelsthorPE, Manchester Museum
12. GCG OM 2013-2015 Emma Bernard NHM, London
David Notton will continue to work for the committee as peer reviewer / referee for our Journal.

Any Other Business

The outgoing Chair reported to AGM that next year's AGM and conference will be held in Bristol on 26th – 27th February 2015(to be confirmed). We look forward to seeing you there! The theme still to be decided.

MOU to be uploaded to the NatSCA website so members can read through the document and provide feedback and ideas about how we would like this partnership to work.

Sam Barnett also requested a copy of the Journal as he has not received the last issue yet.

Vote of thanks

AGM thanked all the organisers of the joint SPNHC/NatSCA conference, especially the local committee for all their work and to the staff of the National Museums Wales for a most enjoyable and informative conference.

Simon Moore, Kate Andrew, Tony Irwin, Nicola Newton, David Notton, Claire Mellish and Beulah Gardner are retiring from the committee this year. We hope that we will continue to see them all at NatSCA events and we extend our thanks to them and wish them all the best for the future.

By proposal of Jack Ashby, the membership also thanked the outgoing Secretary Paul Brown and Chair Clare Brown for their work for NatSCA over the past years in those posts.

Close. The meeting closed at 12.45

Next Committee meetings
Horniman Museum and Gardens -19th of September 2014
Grant Museum of Zoology -December 2014 Date to be confirmed
National Museums Liverpool - Date to be confirmed

Paul Brown, Department of Entomology, Natural History Museum, Cromwell Road, London SW7 5BD Tel: 0207 9425196, e-mail: p.brown@nhm.ac.uk

NatSCA
Natural Sciences Collections Association