THE EVOLUTION OF MARITIME CONSERVATION

O Millar, M Thomas and **J Monasta**, Beckett Rankine, UK

SUMMARY

The conservation of historic vessels is becoming increasingly challenging. This paper highlights the shift from functional conservation during a ship's active service to the unique constraints of preserving historic vessels. The financial, structural, and emotional complexities of maintaining historic ships are explored, including the increasing difficulty in obtaining funding, the impact of modern regulations, and the loss of traditional shipbuilding skills on conservation efforts. The challenges faced in maintaining historic ships by small groups without formal training, limitations in regular access to dry docks, and dependence on visitors, donations, and external funding for financial sustainability are highlighted. However, the adversity facing maritime heritage has resulted in the application of new and innovative approaches. Modern technology has enabled the development of safer and more sustainable alternatives to historical practices and materials, offering improved performance and safety at reduced cost. Methods discussed include the use of impressed current systems and galvanic anodes to minimise corrosion, as well as modern paint systems and dehumidifiers to control humidity and reduce moisture levels. The paper also addresses the challenges of working within regulations, emphasising the importance of modern techniques in mitigating risks and ensuring the health and safety of workers.

1. INTRODUCTION

During their working lives, ships undergo functional conservation. They are repaired and maintained as necessary to ensure their ongoing operability. This work is financially viable due to the vessel's future earning potential and intrinsic value. Maintenance is done by the crew whilst at sea, typically including dedicated shipwrights or mechanics, and by specialist teams when dry-docked at regular maintenance periods.

As working ships transition to historic vessels, their conservation must be delivered within different constraints. Preserving historic ships is a complex balancing act between many, often competing, factors. Small groups often maintain historic ships without formal training or certified skills (NHS-UK, 2010). Due to financial, geographical, and mobility constraints, regular access to dry docks cannot be guaranteed. These ships depend on visitors, donations, and external funding for financial sustainability (Keown et al., 2024; BOP Consulting & Raybel Charters, 2024). Constant consideration is required for financial sustainability, structural integrity, preservation of historic fabric, interpretation, and accessibility. Successfully navigating this puzzle is challenging for owners, curators, and volunteers. The emotive nature of historic ships can further complicate this challenge.

In recent years, this situation has become increasingly difficult. Obtaining financial support, such as lottery funding, has become progressively more competitive (Keown et al., 2024). Modern regulations have forced up the cost and complexity of works, threatening maintenance and restoration delivery. The long-term decline of the United Kingdom's shipbuilding industry (Stott, 2023) has resulted in the loss of skills necessary to maintain the vessels and the neglect or demolition of the required facilities. Replicating historical methods and materials can come at an exorbitant cost, beyond the reach of many vessels. These difficulties have placed many historic vessels in precarious positions, resulting in the sinking or loss of ships including the *Esther,* HMS *Bronington,* and PS *Lincoln Castle*.

In practice, access to funding is the primary constraint on conserving historic ships. Operational costs are typically covered by paying visitors, public donations, and hosting events. These sources are often insufficient to address the full maintenance requirements, and as a result, the vessel's condition degrades over time. This places greater reliance on delivering major restoration campaigns at regular intervals. Such campaigns are generally funded through external bodies, such as the National Lottery Heritage Fund and the National Heritage Memorial Fund in the UK. However, the demand for these funds is ever-increasing as more vessels find themselves in similar circumstances (Keown et al., 2024). As such, historic ships can find themselves trapped within cycles of limited, low-quality maintenance, interspersed with sparing restoration campaigns that are small in scope due to financial constraints.

However, the adversity facing maritime heritage is resulting in the application of new and innovative approaches. Modern technology has enabled the development of safer and more sustainable alternatives to historical practices and materials. These are easily applicable, readily available, and often offer improved performance and safety at reduced cost.

This paper examines the increasing difficulties facing historic vessels, including their causes and consequences. The evolution of conservation practices in response to these challenges is then presented and discussed. Various case studies are referenced, and comparisons are drawn between ships' treatment during their operational lives.

2. THE CHALLENGES OF HERITAGE CONSERVATION

2.1 Sporadic Maintenance

While ships are at sea, active maintenance is a constant activity, used partly to occupy the crew. Maintenance is focused on functionality, with components repaired or replaced as necessary to ensure ongoing use. Inspections and upgrades are carried out after pre-determined periods as part of an established maintenance regime. Larger ships like RRS *Discovery* and HMS *Belfast* counted carpenters and engineers among their crew and contained dedicated workshop spaces aboard. As such, a general level of competency was present throughout the crew, led by specialist experts. When dry-docked, restoration campaigns are undertaken by dockyards with large and experienced workforces that they can call upon. In this way, ships undergo constant upkeep, punctuated by regular overhauls and renovations.

Apart from the most prestigious and well-funded vessels, historic ships within the United Kingdom generally employ small maintenance teams. These consist of highly motivated individuals who are passionate about their work. Their efforts are supplemented by volunteers, who are vital for bonding ships to their communities. Volunteers can include people with relevant skills and knowledge and are a cost-effective resource. However, both staff and volunteers have varying levels of ability and experience. This limits the activities they can carry out, the quality of their work, and the independence they can be given. Insurance conditions can place additional constraints on their efforts, alongside the availability of equipment and materials. Staff and volunteers are crucial to a vessel's continued survival. They are often very aware of the maintenance issues of their vessels, but financial restraints present a challenging maintenance environment, which can often negatively impact morale and engagement.

Due to financial dependence on visitors and staffing limitations, many historic vessels are treated primarily as attractions, rather than ships. As such, maintenance regimes are often inadequate and fail to consider what is appropriate for the physical structures of the vessel and its long-term longevity. Cosmetic issues are regularly prioritised over repairs, such as repainting degraded structures. On timber ships, it is common for timbers to be painted when they should be left exposed, with certain paints trapping water and promoting rot. Underlying issues are hidden under a veneer of good maintenance, which can prevent a true assessment of their condition.

Simultaneously, monitoring is often limited. Surveys are limited to visual inspections and do not extend to intrusive measures. Where critical structures such as the hull are covered by partitions or interpretational material, these are generally not removed regularly enough to allow for continued access and monitoring. This enables minor issues to increase in significance over time, with small problems, such as minor water ingress sources, fungal growth areas, or paint coating loss, rapidly escalating to threaten the structural stability and integrity of the vessel.

2.2 Loss of Supporting Industries

Increasing maintenance complexity is closely linked to the disappearance of the industries which created and supported the historical vessels during their operational lives. Stott (2023) estimates that the UK's share of global commercial shipbuilding was over 80% in 1892, while in 1992 it was negligible. The gradual loss of skills across the United Kingdom has made the procurement of the required maintenance increasingly complex and expensive.

This is exemplified in large timber ships. RRS *Discovery* was launched in Dundee in 1901, where it is now the centre of a museum. From the 1990s to the 2010s, one local boatbuilding company regularly carried out repairs to *Discovery*. However, no local companies expressed interest when a tender package for major restoration works was issued in 2022. Shipwrights with the necessary skills and experience for working on major timber ships are now extremely rare. Similarly, welding techniques have predominantly superseded riveting, presenting challenges for ships with riveted hulls such as TS *Glenlee.*

The loss of facilities causes further challenges. While there were once numerous dockyards and dry docks in which ships could be repaired or restored, many have been abandoned or infilled. For example, of the nine Royal Navy Dockyards operational in the UK in the mid-19th Century, only two (Portsmouth and Plymouth) remain operational (Royal Museums Greenwich, n.d.). Procuring suitable working docks is now difficult and costly, threatening ships' ability to dock regularly and contributing to the degradation and loss of historic fabric. HMS *Unicorn* has not been dry-docked since 1972, and the inability to reach a working dry-dock is a primary factor in this. It is trapped within a dock basin by a broken dock gate, which has been left as such for over a decade and has no prospect of imminent repair.

In addition, obtaining materials readily available in the past is no longer practical. Major timber ships typically contain large timber sections in the frames, main longitudinal elements and key other structural elements, with timbers of these requires sizes difficult to find in suitable sizes and quality. Historically accurate materials, such as teak, pitch pine and Riga fir, are no longer affordable. Even in available timbers, such as oak, sections of the original size are not on offer. As such, replicating original methods can have an exclusive price beyond most vessels.

2.3 Legislative Requirements

Increasingly stringent health and safety regulations also affect the ability to maintain historic ships. Materials such as lead paint and asbestos were historically used throughout ships, with minimal precautions in application or removal. Awareness of the health hazards they entail means that specialist contractors with specialist protective equipment are required for their extraction, with high associated costs. Several areas of HMS *Belfast* are inaccessible without specialist equipment, and the *Arctic Corsair* has recently undergone an extensive asbestos removal campaign, which would not have been possible without council and lottery funding. HMS *Warrior* has a large quantity of lead paint on many interior surfaces.

Simultaneously, working practices are subject to more stringent requirements. Practically all large historic ships contain confined spaces with difficult access. HMS *Belfast* has over 60 internal tanks. These spaces need to be accessed periodically for inspection and corrosion prevention works. Many of these spaces are damp and contain corrosion and these conditions cause hazardous environments, such as oxygen-deficient spaces, to develop over time (Manwaring, 1998). As a result, these areas can be extremely dangerous. Access is restricted by the Confined Spaces Regulations 1997 (Great Britain, *The Confined Spaces Regulations 1997*) and can only be accessed with specialist teams and equipment. Other relevant works subject to further legislation include working on rigging, covered by the Working at Height Regulations (Great Britain, *The Work at Height Regulations 2005*) introduced in 2005, and diving, under the Diving at Work Regulations (Great Britain, *The Diving at Work Regulations 1997*) introduced in 1997. Health and safety requirements can frequently result in work being unachievable due to cost or safety concerns.

While these regulations have increased costs and complexity of many tasks, it should be noted that they have been fundamental to improving working conditions and safety at work, with worker safety in Great Britain significantly improved since their introduction. The rate of fatal injuries for workers in Great Britain has fallen dramatically since the introduction of stricter legislation, with 0.42 deaths per 100,000 in 2023/24 compared to 2.1 deaths per 100,000 in 1981, according to the HSE (2024). It is thus also imperative that owners and operators of historic ships should challenge previous practices and introduce innovation to enable the ongoing preservation of vessels.

3. RISING TO THE CHALLENGE

The difficulties facing historic ships can make their future appear uncertain and, at times, bleak. However, the authors of this paper reject this outlook. Difficulties are driving the development of novel techniques that offer more efficient, cost-effective, and safer working methods. This section outlines just some of the innovations used on vessels in the last few years, with these intended to facilitate maintenance and provide solutions that are more cost-effective, safer and more effective than traditional methods.

3.1 Reducing Maintenance Obligations

Maintenance is an ongoing and unavoidable requirement for historic ships. To remain financially sustainable and prevent the loss of historic fabric, a major focus of modern methods is to reduce the amount and frequency of intervention. Capital projects provide a clear opportunity for this.

An impressed current system was installed aboard HMS *Belfast* in 2019. A low potential difference is induced between the hull and the surrounding river through a network of anodes below the waterline. This inhibits the corrosive electrochemical reaction, minimising ongoing section loss. Dive surveys have since validated its effectiveness. Where the hull's external paint coating has failed locally, no evidence of corrosion is visible. Cathodic protection systems are a cost-effective method of reducing maintenance requirements and are relatively simple to fit vessels retrospectively. By installing this system, the drydocking period for the vessel has been extended.

Galvanic anodes are another method of reducing the maintenance periods. The *Spurn Lightvessel* has recently undergone an extensive restoration campaign, with a large series of galvanic anodes installed. These were more extensive than would traditionally be used, aiming to increase the period required between drydocking. Neither of these technologies is new, but by retrofitting them to vessels, maintenance requirements can be minimised and dry-docking intervals extended.

SS *Great Britain* underwent a major restoration project in the 2000s aimed at halting active corrosion of the original hull. This was achieved by constructing a glass structure around the vessel's waterline (Watkinson & Tanner, 2008). This creates a sealed environment within the dock, which environmental systems can control more easily. A desiccated air system was installed to keep the humidity at the vessel's hull within acceptable limits. This uses real-time monitoring to adapt to the humidity conditions, helping to minimise energy requirements.

The *Cutty Sark* also underwent a major restoration campaign in the early 2000s. Due to concerns about the condition and longevity of the ship's wrought iron framework, removing chlorides was a key priority. As such, the ship was subject to electrolytic treatment, which was found to cause a 78% decrease in the chloride content within the iron frame and joints. This campaign also involved the installation of a complex cradle structure, seeking to reduce the deformation of the hull caused by previous propped supports.

A core cause of structural degradation on both timber and metal-hulled ships is the penetration of moisture, which causes paint breakdown, rust and rot. Its entry is challenging to mitigate, particularly within public spaces. Techniques such as dehumidification offer a way of reducing moisture levels. Dehumidifiers are simple to install and operate and can be low cost and effective. Although a method of water disposal is required, they can help to reduce maintenance burden and the need to access confined spaces. The installation of dehumidifiers into difficult to reach spaces was specified as part of restoration work to HMS *Warrior* for ballast storage spaces. Here, the ballast prevents access to the underlying structures, and hence active intervention measures such as paint coating are not feasible. Passive dehumidification provides an optimal alternative.

3.2 Working Effectively Within Regulations

As discussed previously, legislation can complicate the conservation of historic vessels. This added complexity makes it easy to view regulations as obstructive. However, their fundamental purpose is to improve the health and safety of workers**,** and they serve as a vital framework behind good working practices. Although many risks when working on historic ships cannot be eliminated, they can be reduced to an acceptable level through modern techniques.

Confined spaces cannot practically be removed from ships without compromising their structural integrity and historic fabric. Access can be improved through the creation of new hatches, as proposed for the double bottom of HMS *Warrior*, but restrictions on entry remain. Instead, conservation efforts often focus on reducing the need to access them regularly. This is achieved by removing the destructive components that cause corrosion and section loss. Paint coatings are the traditional means of preventing corrosion by forming a material barrier between the metal and moisture. Surface preparation is crucial for effective coating longevity, which traditionally requires shot-blasting. However, shot blasting within confined spaces poses a significant health and safety risk. These risks can prevent coating entirely or significantly increase the complexity and cost.

Modern paint coatings can be applied to surface standards as low as St 2, requiring only light manual cleaning. A solvent-free, wet & rust-tolerant epoxy coating has been proposed aboard HMS *Belfast* to coat the interior tanks. Using these coatings significantly reduces the need for operations within confined spaces, lowering operatives' risks. Alternatively, Vapour Corrosion Inhibitors (VCIs) can be released into the confined space. These settle across the structures, creating a protective layer that prevents oxidising reactions. VCIs require only minimal prior preparation. This system has been specified as part of the restoration of the *Arctic Corsair* for tanks which are not accessible.

Remote technologies offer further opportunities for reducing risk. Dive surveys are still generally relied upon for high-quality observations of submerged hulls. These can be dangerous operations, particularly in the presence of fast currents. In addition, their quality is variable and dependent on visibility and marine growth. Hydrographic surveys offer a safer and often cheaper alternative. While they cannot always produce the same level of detail, they can provide valuable information on shape and deformations, adequate for many purposes. Alternatively, scans can be carried out within the vessel. A detailed 3D model of HMS *Unicorn* was produced in 2020 through aerial and internal scanning. These were then extrapolated to estimate external hull profiles. These estimates were then used as the basis for stability calculations on the vessel.

Similarly, working from Mobile Elevated Working Platforms, such as scissor lifts or cherry pickers, can mitigate the risks associated with working at height in ship rigging. Drones can also be used for visual reconnaissance taking high-quality photogrammetry and LIDAR scans. Although they cannot qualitatively assess the condition of materials and structures, they can take high-quality images and provide views that cannot otherwise be reached. As such, they can help supplement and guide rope access surveys.

3.3 Overcoming Shortages

The loss of the supporting industries around historic ships has caused various changes in their conservation. For example,
the lack of available dry docks has pushed many vessels to secure permanent dry berths. This aims to remove the ships from harsh environments and allow ready access to their structures for maintenance. Removing ships from water changes the load paths through their structures and can result in long-term deformation and damage to components. As such, several vessels have complex cradle structures to distribute loads more evenly across their hull, including HMS *Victory* and the *Cutty Sark*.

On the other hand, where ships are unable to dock, such as HMS *Unicorn*, modern techniques allow intervention to support ageing and degraded structures. Advanced structural modelling techniques allow recreation of ships' structures, analysis of weaknesses and possible failure mechanisms, and design of targeted intervention. This helps to ensure the ongoing survival of the ship while minimising damage and loss of historic fabric.

The difficulties in obtaining timber sections of the original size are being overcome through techniques such as lamination. This uses the application of glue and pressure to combine smaller timber sections. The glue is designed to behave in a compatible manner with the surrounding timber, and can be used in both curved and straight sections. While non-authentic, lamination provides an affordable solution for the replacement of timbers. The

laminated section can be designed to give the external appearance of a single section, reducing curatorial impacts. Laminated timbers are in use within the hull timbers of HMS *Victory* and are under consideration for key components such as the stern horn timbers on RRS *Discovery.*

Shortages in expertise are being addressed through apprenticeship and training schemes. The Worshipful Company of Shipwrights supported an 8-year scheme from 2014, employing 125 young people on formal Level 3 apprenticeships with 94 small marine businesses (Worshipful Company of Shipwrights, n.d.). The Scottish Boat Building School in Irvine was established in 2014 to provide education in both traditional and modern boat building and repair, with an apprenticeship scheme launched in 2019 (Harrison, 2019). Contractors working on an ongoing restoration project to RRS *Discovery* are collaborating closely with staff and the Scottish Maritime Museum to share skills and techniques. National Historic Ships UK (NHS-UK) has established the Shipshape Network to encourage collaboration within maritime heritage and ship conservation. External consultants can provide ship owners with guidance and project management abilities, interfacing between curators and contractors to support the successful delivery of projects.

To replace the role of classification societies, which provide maintenance schedules during a ship's working life, a framework for the maintenance of historic ships is provided by NHS-UK. Through a statement of significance and a Conservation Management Plan (CMP), the conservation priorities for the vessel are established. These are then used as a basis for the Maintenance and Management Plan (MMP), a vital tool in successful conservation. The MMP should identify the works and inspections required, alongside the intervals at which each measure must be carried out. MMPs must align closely with the CMP, which sets out the significance of heritage assets and the guiding principles behind their conservation and management.

MMPs should be revisited and updated regularly, reflecting their effectiveness and incorporating updated techniques and knowledge. However, they also need to be sufficiently flexible to allow changes in funding and staff capacity. When funding is limited, the prioritisation of intervention measures becomes more important. The MMP must support decision-making, providing a framework for consistent and systematic implementation that ensures the survival of the vessel.

4. CONCLUSIONS

The conservation of historic vessels involves many challenges, including low-quality maintenance, heightened legislative restrictions, and the disappearance of supporting industries. These increase the cost and complexity of works, threatening the financial sustainability of historic ships and contributing to the degradation and loss of historic fabric.

Conservation techniques are changing to overcome these challenges. Maintenance requirements are minimised through dehumidification and desiccant systems, electrolysis treatment, and cathodic protection. Ships are permanently located within docks, and advanced cradle systems used to reduce impacts on their structures. Techniques such as lamination are reducing the reliance on large timber sections. Systems such as drones, hydrographic scans, corrosion-resistant paint, and VCI systems can reduce risks and help comply with regulations. While some historical methods must be retained for authentic maintenance and restoration of vessels, others are made impractical by financial and legislative constraints. Here, alternatives must be sought in the shipbuilding industry and beyond.

As technology continues to develop, the conservation of historic ships will evolve commensurately. Many approaches that are relatively novel in their application to historic ships have extended records of use in other industries. Lamination has long been used in structural timber, hydrographic scans are used for mapping channels and submerged infrastructure, and impressed current is used regularly in modern ships. These engineering approaches are highly applicable to historic ships and offer opportunities to reduce costs and increase efficiency. Conservation of historic ships can learn much from the methods employed in other situations and benefit greatly from their application.

5. ACKNOWLEDGEMENTS

We want to thank Wynford Davies for his continued support and advice throughout our projects. We would also like to thank all our Historic Ships clients for their ongoing collaboration and support, with a particular mention to the Hull City Council Project Delivery Team, the Imperial War Museum, the Dundee Heritage Trust, the Unicorn Preservation Society, Hartlepool Borough Council, and the National Museum of the Royal Navy. Finally, we would like to acknowledge Tim Beckett and Gordon Rankine for the opportunity to work on these incredibly interesting and exciting projects.

6. REFERENCES

National Historic Ships (NHS-UK) (2010) *Conserving Historic Vessels.* London, UK, National Historic Ships.

Keown, K., Motin, M., Gibson, L. & Ali, L. (2024) *On the Brink: Heritage in the Cost of Living Crisis.* The Heritage Alliance. https://www.theheritagealliance.org.uk/wp-content/uploads/2024/05/On-The-Brink-Heritage-in-the-Cost-of-Living-Crisis.pdf

BOP Consulting & Raybel Charters (2024) *Historic Ships Research* Source: Historic Ships Research (heritagefund.org.uk)

Stott, P. (2023) Shipbuilding Policy in the UK: The Legacy of a Century of Decline and its Influence on Naval Procurement. *The RUSI Journal*, 168(5), 54–67. https://doi.org/10.1080/03071847.2023.2250389

Royal Museums Greenwich (n.d.) *Research Guide B5: Royal Naval Dockyards.* https://www.rmg.co.uk/collections/research-guides/research-guide-b5-royal-naval-dockyards [Accessed 9 September 2024].

Manwaring, J. (1998) Confined Spaces Hazards Facing the Corrosion Engineer in Alaska. In: Corrosion 98. San Diego, California. NACE Corrosion.

Great Britain. *The Confined Spaces Regulations 1997: Elizabeth II.* (1997) London, The Stationery Office.

Great Britain. *The Work at Height Regulations 2005: Elizabeth II.* (2005) London, The Stationery Office.

Great Britain. *The Diving at Work Regulations 1997: Elizabeth II.* (2005) London, The Stationery Office.

Health and Safety Executive (2024) *Work-related fatal injuries in Great Britain, 2024.* Health and Safety Executive. https://www.hse.gov.uk/statistics/assets/docs/fatalinjuries.pdf

Watkinson, D. & Tanner, M. (2008) SS Great Britain: Conservation and Access – Synergy and Cost. *Studies in Conservation,* 53, 109-114. https://doi.org/10.1179/sic.2008.53.

7. AUTHORS BIOGRAPHY

Oliver Millar is an Engineer at Beckett Rankine. He has a Master's Degree in Civil Engineering from Imperial College London. He is engaged in projects across the marine sector, including the ongoing conservation of HMS *Unicorn* and RRS *Discovery*.

Mark Thomas is a Naval Architect at Beckett Rankine. He has a Master's Degree in Maritime Engineering Science/Offshore Engineering from Southampton University and joined BR in 2019. Since then, he has been involved in many historic ship conservation projects, including HMS *Belfast* and RRS *Discovery*. Most notably, over the past three years, he has been the Owner's Representative for the restorations of the *Arctic Corsair* and *Spurn Lightship*.

John Monasta is a Principal Naval Architect at Beckett Rankine. He graduated from Strathclyde University in 2013 with a Master's Degree in Naval Architecture and Ocean Engineering. Following a career that included working in the offshore energy sector and on large infrastructure projects in London, such as the Crossrail and the Thames Tideway projects, he joined Beckett Rankine in 2018 to develop a new Naval Architecture department in the company. As part of this, he expanded the Historic Ship capability and developed this into a core business and specialism within Beckett Rankine. Has worked on the conservation of many historic ships across the UK, from HMS *Unicorn* in Dundee to HMS *Belfast* in London, to the historic trawlers *Arctic Corsair* and *Ross Tiger* on the Humber River, and others.