THE NATIONAL MUSEUM ROYAL NAVY

HMS Victory Conservation Programme Plan

Report No. 1

Choice of timber species for replacement of structure and planking

1. Introduction

1.1. The overriding aim of the HMS Victory project is to undertake a programme of conservation to deliver a fully conserved HMS Victory, in an open environment, and in a condition to survive for 50 years without major work beyond a programme of planned maintenance.[1]

1.2. The ship's material state has been assessed as poor, due largely to rot present in both historically significant and relatively modern (post-1965) material.[2] Structural analysis of *Victory* has concluded that, despite the presence of rot and insect infestation, the ship's structure is, in its present condition, capable of resisting foreseeable short-term loadings.[3]

1.3. Both the shipwright's survey and structural analysis reports highlight the need to prevent rainwater leaking into the ship.[4] The current system of hull planking, employing laminates of iroko and teak, is largely decayed and forms an environment which, according to a 2010 English Heritage Report, 'is analogous to rotting logs on a forest floor'.[5] Given its condition, it is impossible to render the existing hull planking weathertight in the medium to long term; resource-intensive remedial work is required to minimise water penetration in the short-term.

1.4. The need to replace material in the ship's hull is not, therefore, predicated upon the structural needs of the ship, but upon the pressing need to prevent water from entering the structure and damaging archaeologically significant material.

1.5. The HMS Victory conservation management plan (CMP) states that 'Previous choices of timber species and methodology, particularly in respect of the hull planking, have been shown to have been inappropriate, and to have actually accelerated the deterioration of the ship's fabric. It is vital that all future decisions

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[1] Wessex Archaeology, *HMS Victory, Portsmouth Historic Dockyard - Conservation Management Plan*, November 2014, para 9.1.1

[2] T. Nielsen & Co., *HMS Victory - Shipwright's Internal and External Surveys*, 2012.

[3] Fenton & Holloway, *Modelling and structural analysis of HMS Victory: Report*, Feb 2014, summary.

[4] T. Nielsen & Co., *HMS Victory - Shipwright's Internal and External Surveys*, 2012, p. 141; Fenton & Holloway, *Modelling and structural analysis of HMS Victory: Report*, Feb 2014, summary.

[5] English Heritage, *A report on decay in the hull timbers of HMS Victory*, 2010, p1.

are based upon clear evidence of suitability, by recommendation from other projects, or through empirical analysis.'[6]

1.6. Policy 26 of the CMP directs that a decision regarding timber choice for necessary replacement of planking and structure will be made based upon 'research, precedent or modelling.'[7] The CMP goes on to state that, in principle, timber species employed in the conservation work will be:

- Known by experience, experiment or modelling to perform well in the location proposed.
- Ethically sourced
- Visually appropriate for its location on the ship

1.7. Policy 28 of the CMP stipulates that material will be replaced on a 'like for like' basis except where:

- The material to be replaced has proven defective and inefficient for its role.
- The correct quality of timber of the selected species is unavailable at an acceptable cost.
- Past experience on *Victory* or comparable vessels has proven that an alternative would perform significantly better in terms of durability.
- An alternative would bring particular benefits to the character and presentation of the ship.

1.8. In order to comply with these policies and prepare a programme plan to deliver the overriding aim of the project, a working group was established as part of Contract SC166 HMS Victory Survey, Repair, Maintenance, Conservation, Design & Research Services under WAF 166/200.

1.9. The working group included representatives of BM TRADA, English Heritage, Eura Conservation, T. Nielsen & Co., The National Museum of the Royal Navy, BAE and Artelia.

1.10. This report presents an overview of the working group's investigations along with recommendations for assumptions on choice of timber species for replacement structure and planking of HMS Victory.

2. History of timber choice in conserving HMS Victory

2.1. At the time of *Victory's* docking in 1922, the timbers to be found throughout the ship were largely of the species employed at the time of construction, use and repair as a seagoing ship. The choice of timber employed in *Victory's* hull was dictated by the characteristics of available species. The keel and garboard strakes were of elm, noted for its availability in great length, irregular grain and durability in seawater, whilst English oak was used throughout the rest of the ship's structure, with the possible exception of the sheer strakes where East Country Plank may have been employed.[8]

[6] Wessex Archaeology, *HMS Victory, Portsmouth Historic Dockyard - Conservation Management Plan, November 2014*, para 10.6.3.
[7] Wessex Archaeology, *HMS Victory, Portsmouth Historic Dockyard - Conservation Management Plan*, November 2014, Policy 26.
[8] B. Lavery, *The ship of the line - volume 2: Design, construction and fittings*, Conway Maritime Press, London,1997, p 29; P. Goodwin, *The construction and fitting of the sailing man of war 1650-1850*, Conway

2.2. In the course of the 1920s restoration work, a variety of timbers were used dependent upon cost and availability; oak was used alongside fir for the replacement of frames, beams and inner planking. The outer planking from the sheer to the main wale was sheathed in teak to restore the sheer of the planking which had been lost due to the numerous patch repairs made in the 19th century. Critically, the oak used at this stage was not well seasoned and inferior in quality to that used before and since[9]

2.3. In 1955 a timber specification was developed: teak was to be employed for all structural members that were enclosed or buried on three or more sides (timbers, external planking, internal stringers, lining) and oak was used for those items exposed on three sides (riders, beams, keelson) the intention being such items could continue to season in place after being fitted.[10]

2.4. In 1981, the VATC formed a subcommittee to consider and advise on future repair methods for use in the event of the then methods and materials becoming too expensive or unavailable. In its 1984 final report, this committee reported that teak remained in use throughout the ship in both solid and laminate form, iroko had been trialled as a material and found acceptable, and softwood permeable to treatment with chromated copper arsenate preservative would be as resistant to decay as teak or iroko. Should such treated timber be employed, however, there would be a need to return to fastening members by treenails as copper preservative is liable to react with ferrous fixings.[11]

2.5. In 1986, iroko was adopted as the primary timber (by volume) for use in *Victory*.[12] Inner lining, beam ends and knees from this date on were fabricated in iroko, whilst the external hull planking was built up of an outer laminate of teak and inner laminates of iroko. The ship's frames continued to be replaced in teak.[13] It appears that the policy of using oak where three or more faces were exposed continued on paper at this time, but the widespread use of iroko in these roles, which is currently in evidence on board, would suggest that practice may not have followed policy. By 1989 it is clear that although the use of oak in *Victory* was not prohibited, for reasons of availability and costs its use was in abeyance.[14]

2.6. In 1996, following the discovery of extensive rot in the iroko laminates of outer planking (first noted in 1993), a policy adopting teak as the exclusive timber for restoration was introduced.[15] This was modified at a meeting of the VATC in September 1997 to allow the continued use of iroko for internal elements such

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Maritime Press, London, 1987, p50; A.R.Bugler, *HMS Victory - Building, Restoration & Repair*, HMSO, London, 1966, p. 129.

[9] Bugler, p. 49, p. 96, p. 113.

[10] Bugler, p. 98.

[11] VATC Sub-committee on timber, *Final Report*, 1 March 1984. para 6.

[12] VATC sub-committee meeting, *Minutes of meeting*, 18th March 1996, para 2.

[13] VATC sub-committee meeting, *Minutes of meeting*, 18th March 1996, para 10c.

[14] VATC sub-committee meeting, *Minutes of meeting*, 21st February 1989, p. 1.

[15] VATC sub-committee meeting, *Minutes of meeting*, 18th March 1996, p7.

as lining and beams.[16] Iroko continued to be used in laminate form until the restoration programme was completed in 2002.[17]

2.7. In 2002, MOD began work to identify appropriate sources of teak to replace defective material.[18] This work resulted in the procurement of wild-grown teak from India, laminated into boards in Lincolnshire. In the summer of 2007, following the delivery of 6,394 laminated boards, MOD withdrew from the Indian market due to significant price escalation.

2.8. Supplies of wild-grown 'historic' teak were identified in Thailand, felled before the 1989 Thai logging ban. Delivery of 4,966 boards, laminated in Thailand, commenced in July 2008 and concluded in May 2010. This teak was believed to be of better quality than that sourced in India, due to the dimensions of individual baulks and the age at felling.[19]

2.9. These timber stocks are held in store and are estimated at 510m^3.[20]

3. Problems of rot and insect infestation

3.1. On docking in 1921, significant rot was discovered at the level of the middle gun deck and the tumble home, requiring large-scale replacement of the frames and hull planking at that level.

3.2. By 1932 water penetration, leading to rot and insect infestation, was confirmed in many parts of the ship. Rot had spread throughout the oak elements of the ship, but also into the teak hull sheathing around the bow.[21] The ingress of fresh water had allowed rot to modify the oak making it susceptible to attack from deathwatch beetle. By 1947, deathwatch beetle numbers reached a peak when 16,000 individual beetles were caught. A three-year programme of fumigation was implemented which had a dramatic impact upon beetle numbers.

3.3. From 1955 onwards fumigation, combined with the replacement of decayed oak with more durable hardwoods, has reduced the scale of the deathwatch beetle infestation. Deathwatch beetle activity continues in oak timbers which, although now dry, have been modified by earlier fungal attack.

3.4. Despite an understanding of the importance of keeping rainwater out of the ship's structure, the approach to *Victory's* conservation between 1955 and 2000 was predicated upon completing the restoration package in time for the Trafalgar bicentenary. Fluctuations in spending helped to ensure efforts were directed to completing restoration rather than preventing water ingress. The legacy of this approach is clearly demonstrated by the ship's material state.

3.5. Any approach to the ship's conservation which focusses on the use of durable timbers to ensure longevity will result in the loss of the remaining significant material in the ship. Selection of appropriate timber species is of critical importance in delivering a sustainable approach to the ship's conservation only

[16] Fleet Maintenance & Repair Organisation, *HMS Victory progress report*, February 1997, p2.
[17] Fleet Support Limited, *HMS Victory restoration and maintenance progress report*, October 1999. p3.
[18] VATC & MWAB Extraordinary timber committee meeting, *Minutes of meeting*, 14th October 2002.
[19] VATC 107th meeting, *Minutes of meeting*, 21st May 2008, p. 10.
[20] BAE, *V2014.08 HMS Victory – Timber Stock,* 13th May 2014*,* p. 1
[21] Bugler, p. 86.

if matched by a commitment to undertake regular maintenance to ensure the external surfaces are kept weathertight.

4. Assumptions

4.1. The process by which appropriate timbers can be selected for use in the ship is predicated upon several assumptions:

- A planking system will be adopted which, with planned maintenance, will ensure that the hull is kept weathertight.
- The Board of the HMS Victory Preservation Company will commit to making available the funds necessary to undertake all planned maintenance.
- The deathwatch beetle infestation on board HMS Victory will be eradicated in the course of conservation work.

5. Timber Durability and Use Classes

5.1. The resistance of timbers to fungal decay and wood boring insect attack varies with species and geographic origin. Timber available commercially on the scale required for the *Victory* conservation programme can be assigned to one of five durability classes (DC) listed in EN 350-2, ranging from DC1 Very Durable to DC5 Not Durable.[22]

5.2. Durability relates only to heartwood and not sapwood. No timber species has durable sapwood.

5.3. Five Use Classes for timber are defined in EN335 as follows:[23]

UC1 Timber is under cover, fully protected from the weather and not exposed to wetting.

UC2 Timber is under cover and fully protected from weather, but where high environmental humidity can lead to occasional but not persistent wetting.

UC3 Timber is not covered and not in contact with the ground but is either continually exposed to the weather or is protected but subject to frequent wetting.

UC4 Timber in contact with ground or fresh water; permanently exposed to wetting.

UC5 Timber is permanently exposed to wetting by salt water.

5.4. From these standards, BM TRADA applied use classes to HMS Victory's hull structure as follows:[24]

Coated timber exposed to the weather (hull planking, UC 3

[22] BM TRADA, *V2014.13 Selecting timbers suitable for the replacement of external hull planking*, May 2014, p4; EN 350-2:1994, *Durability of Wood and Wood-based Products – Natural Durability of Solid Wood: Guide to natural durability and treatability of selected wood species of importance in Europe*

[23] EN 335:2013, *Durability of wood and wood-based products – Use classes: definitions, application to solid wood and wood-based products*

[24] BM TRADA, *V2010.40 Answers to questions raised in email dated August 1st 2014,* August 2014, pp. 1-2.

capping, gun port linings &c.)

Timber within hull structure protected from weather which may be subject to occasional wetting should outer planking/caulking fail. (ship's frames)	UC 2
All internal timber which is under cover and fully protected from the weather, but may be subject to high environmental humidity and occasional but not persistent wetting. (Inner lining, knees, beams, etc)	UC 1

5.5. BS 8417:2011 provides typical service lives for timbers of different DC in different Use Classes (UC) in intervals of 15, 30 and 60 years. Given HMSVPCO's stated aim of delivering a fully-conserved ship in a condition to survive maintained for 50 years, only timbers able to offer a 60 year service life in the relevant usage class formed the long list for evaluation. For each UC, the minimum DC required to deliver a 60-year service life, when coated, is listed below:

UC1 DC 5

UC2 DC 2

UC3 DC 1 & DC2

6. Timber for UC 3 – Hull planking

6.1. Only timbers of DC1 & DC2 are of sufficient durability in UC3 to achieve the conservation aim detailed at Paragraph 1.1. BM TRADA state that external timbers with a maintained coating should exceed a 60-year service life before requiring replacement. If the planking's paint coating is maintained so as to prevent the surface of the timber becoming exposed, decay will not take place and the surface life may be very much longer than the required 50 years.[25]

6.2. Working with T. Nielsen & Co., BM TRADA developed a list of candidate timbers which meet the durability requirement and are workable from a shipwright's perspective.[26]

6.3. In addition to traditional hardwood timbers, BM TRADA also listed modified and preservative-treated softwoods to provide a longlist as follows:

- Teak
- European oak
- Iroko
- Opepe
- Greenheart
- Preservative treated softwood
- Accoya
- Thermowood

6.4. At a meeting of the working group on May 28th the candidate timbers on the long list were discussed:

[25] BM TRADA, *V2010.40*, p. 3.
[26] BM TRADA, *V2014.13,* p. 6; T. Nielsen & Co., *V2014.2 Suitability of timber for planking*, May 2014.

- It was agreed that, given previous experience of iroko in the *Victory* project, any recommendation to continue its use would be contrary to all available evidence.
- Opepe is a suitable timber with a history of boatbuilding use and availability in large dimensions. Given that it is inferior to teak in terms of the occurrence of surface shakes, however, and allowing for the existing store of teak, it was discounted.
- Greenheart, whilst extremely durable is also extremely difficult to work and presents safety concerns. Additionally, its mass is 46% greater than oak and 63% greater than teak. This would result in a significant increase in the weight carried by the ship, support and dock structure. For this reason Greenheart was discounted.
- Although preservative-treated softwood has an extensive history of use, that history does not extend to boatbuilding/conservation. Pressure-treatment provides an envelope of protection which would be compromised in the process of working the timber down to the required dimensions. This would remove a significant portion of the treatment and expose the operative to chemical hazards.[27] Any exposed surface could be preserved by brush application of treatment, but this does not confer the same level of protection as treatment. The occurrence of any checks or splits in timber would also compromise the protective envelope and expose underlying untreated wood to risk from wetting and decay.[28] Alternatively, the element may be treated once it has been made up, but the very large dimensions of some elements may make this difficult.[29] The use of treated softwood was discounted.
- Thermowood is a relatively new, modified wood product. Limited experience and uncertain availability in the quantities required saw it discounted.

6.5. Following discussions, a shortlist of three candidate timbers was agreed:

- Teak
- European Oak
- Accoya

6.6. BM TRADA was commissioned to prepare a paper which compared the qualities of the three shortlisted timbers.[30] T. Nielsen & Co undertook tests of Accoya in order to establish the workability of that timber from a shipwright's perspective.[31]

[27] T. Nielsen & Co., *V2014.39 Reply to questions raised by NMRN*, August 2014, p. 1.
[28] BM TRADA, *V2014.42 Feedback on questions and comments circulated in recent emails*, August 2014, p. 5.
[29] BM TRADA, *V2014.42,* p. 5.
[30] BM TRADA, *V2014.23 Work to evaluate the suitability of candidate timbers for use in HMS Victory*, June 2014.
[31] T. Nielsen & Co., *V2014.27 Workshop test of Accoya timber to help determine its suitability for use on HMS Victory*, July 2014.

6.7. The BM TRADA report makes clear that there is very little difference in suitability between the three timbers. All timbers are capable of meeting the conservation objective on the understanding that they are coated.

6.8. Work by T. Nielsen & Co., however, revealed some difficulties in steam and dry-bending of Accoya. Of most concern, the timber if exposed to moisture takes on and holds significant quantities of water.[32] This is quite different to teak and oak, the heartwood of which is far less permeable than Accoya.[33]

6.9. Consultation on the use of Accoya in the wider conservation field was undertaken through Eura Conservation. This revealed relatively modest use of the material, typically in the repair of historic buildings. Whilst performance to date was reported as being as advertised, the moisture absorption rate, differential movement and unpleasant dust produced when working were commented upon.[34]

6.10. As a consequence of the various investigations and reports into Accoya, its use on *Victory* was discounted due to its permeability, difficulty in bending/working, lack of availability in large dimensions and untested use in large conservation projects.

7. Assessment of oak and teak against required criteria

7.1. Returning to those criteria set forth in the Conservation Management Plan. Any timber selected for the conservation project must:

- Have a minimum 50-year service life
- Be known by experience, experiment or modelling to perform well in the location proposed.
- Be ethically sourced
- Be visually appropriate for its location on the ship

Service Life

7.2. Both oak and teak will provide a 60-year service life where coated, and both can be expected to exceed 60 years provided that the coating is maintained.[35]

Performance

7.3. Oak and teak are both long-established materials for ship construction. Oak is less durable than teak, but evidence from HMS Victory, HMS Unicorn, HMS Trincomalee, HMS Gannett, the Danish frigate *Jylland* and lightship LV50 clearly demonstrates that both oak and teak, if kept dry, offer durability well beyond the required 50-year service life.[36] Similarly, these examples also clearly demonstrate that if either timber is allowed to 'wet-up' through failure to maintain the weathertight envelope, the timber will decay.

[32] T. Nielsen & Co., *V2014.27*, p. 2.

[33] Permeability of timber is assessed by classification, class 1 being easy to treat and class 4 extremely difficult. Accoya is radiata pine which is permeability class 2-3. Oak and teak are permeability class 4. BM TRADA, *V2014.28 Review of Accoya testing (Email comms.)*, July 2014; BM TRADA, *V2014.42,* p.3.

[34] Eura Conservation, *V2014.36 & V2014.37 Comments on Accoya (Email comms.)*, July 2014.

[35] BM TRADA, *V2014.13*, p. 6; BM TRADA, *V2010.40*, p. 2.

[36] T. Nielsen & Co., *V2014.39*; Bugler, passim; A. Lambert, *Trincomalee, the Last of Nelson's frigates*, Chatham Publishing, London, 2002, passim.

Ethically Sourced

7.4. The teak currently in store was sourced according to Defcon 691 *Timber And Wood-Containing Products* and is FSC certified. Oak in the quantities and dimensions required can be sourced with FSC certification.[37]

Visually Appropriate

7.5. The vast majority of the timber in UC3 is, where visible, protected by a coating and both oak or teak are, therefore, visually appropriate for use in that class. The timber in UC2 is not generally visible and aesthetic considerations are, therefore, limited. Timbers in UC1 are generally protected by coatings, with the exception of deck planks. The checking and splitting common in oak elements of large dimension is not to be found in teak and so oak possesses some aesthetic advantage in such use. Nevertheless, both timbers meet the criteria.

7.6. Policy 28 of the CMP states that material shall be replaced on a like-for-like basis except for when:

- The material to be replaced has proven defective and inefficient for its role.
- The correct quality of timber of the selected species is unavailable at an acceptable cost.
- Past experience on *Victory* or comparable vessels has proven that an alternative would perform significantly better in terms of durability.
- An alternative would bring particular benefits to the character and presentation of the ship.

Like for like

7.7. Clearly, replacing the existing material on a like-for-like basis is not appropriate. Flaws in the process of timber selection, planking system design and method of fitting created a system of hull planking much changed from that used in *Victory* throughout her existence until 1965. Replication of the existing planking system would result in failure to achieve the aim of the conservation project. Accepting the principle that material should be replaced on a like-for-like basis, the hull planking as it existed prior to restoration should form the basis for replication. If accepting the system in use between 1922 and 1965 as the basis, this would be replication of an oak-planked hull which had been re-profiled with the use of a surface skin of teak.[38]

7.8. The use of two different timbers to replicate the single-thickness oak planking authentic to the ship's service afloat is also problematic. Differential movement of the timber is a source of concern, whilst relatively shallow plank seams in a teak skin present difficulties in caulking. As with the planking scheme currently to be found in the ship, the teak sheathing placed over the oak hull of *Victory* between 1922 & 1928 was arrived at as a conservation solution which introduced significant problems in preventing water ingress;[39] It would not now be deemed an appropriate conservation solution.

[37] T. Nielsen & Co., *V2014.2.*
[38] Bugler, p. 49.
[39] Bugler, p. 89.

7.9. Given the arguments presented at Points 7.7 &7.8, this report proposes that the starting point for assessment of any like-for-like replacement should be the historically authentic planking of oak for the external hull.

7.10. Replacing like-for-like, therefore, would suggest a traditionally-plank hull constructed of oak. Teak does not meet the like-for-like requirement; *Victory* has never had a teak-planked hull.

Quality & Availability

7.11. In order to comply with replacement on a like-for-like basis, natural timber elements should be used. In both teak and oak, however, the large dimension of individual elements creates issues around seasoning of timber and the risk of heart rot existing unseen. It is proposed, therefore, to adopt 'engineered timber' i.e. individual elements such as planks, knees and beam ends formed from laminates. This route, irrespective of timber choice, allows for timber to be correctly seasoned and guaranteed free from heart rot.

7.12. The teak currently held in store is estimated at 510m^3, whilst the quantity required for external planking is estimated at 210m^3, not allowing for wastage.[40] The stored teak is assumed to be DC1; tests to confirm durability are underway and will complete by February 2015.

7.13. Oak is available at the appropriate quality and an acceptable cost[41]

Durability

7.14. Durability is clearly of utmost concern in selecting an appropriate timber for use in *Victory*. At the time of *Victory's* service, a first rate ship was expected to run no more than eight years before repairs were necessary.[42] Between floating out in 1765 and completing seagoing service in 1812, *Victory* underwent two large repairs, with a third taking place from 1814 to 1816.[43] Recent archaeological studies have tended to confirm the view that by 1802 there was very little material left in the ship from her original construction, and by January 1816 there was relatively little material remaining from that introduced in the 1800-1803 refit.[44]

7.15. By the time *Victory* was dry-docked in 1922, that material found to be rotten (as detailed in paragraphs 2.1-2.2) had likely been in the ship for over a century, dating largely to the 1814-16 refit. Archival evidence supports the assertion that the rot found throughout the ship by 1922 was a (then) relatively recent occurrence. Writing in 1905, Sir Philip Watts, then chief constructor for the Admiralty, stated that '*At the present moment…the* Victory *is in good repair, a large quantity of timber damaged in action and decayed has been removed from time to time, but much of the old vessel yet remains.'* Eighteen years later, the ship's material state had deteriorated significantly: *'…the effects of time have weighed heavily on her. It is no longer true that she is in "good repair." She is in*

[40] Questions exist over the quality of the teak boards held in stock. A programme to assess the quality of the laminated joints is currently underway as is durability testing of the timber, the results of which are not expected until January 2015.
[41] T. Nielsen & Co., *V2014.2.*
[42] R. Morris, *The Foundations of British Maritime Ascendancy: Resources, Logistics and the State, 1755–1815* Cambridge University Press, Cambridge, 2010. P. 158.
[43] Bugler, pp. 20-33.
[44] Wessex Archaeology, *Survey of Timber Marks and Fabric Analysis on HMS Victory*, 2013.

fact very far from that condition. During the intervening years decay has at last set in so rapidly and so extensively that in order to avoid the risk of her foundering at her moorings she was taken into Dockyard hands…'[45]

7.16. It seems reasonable to infer that the absence of appropriate maintenance throughout the First World War and the years immediately succeeding contributed to the rapid onset of rot. The importance of maintenance is also demonstrated through HMS Unicorn, the hull of which is approaching 190 years of age and which was largely intact until well into the 20th century.[46] Similarly, experience with lightship LV50 demonstrates that a ship's hull, if maintained, can exhibit very good durability.[47]

7.17. If HMS Victory's hull planking is maintained in a weathertight condition, no alternative timber appears to offer significant improvements in durability over oak. If the hull planking is allowed to wet-up, however, teak is more durable. Only timbers in DC1 offer 60 years' service life in Usage Class 4 – wood in fresh water.[48] Teak does, therefore, offer an advantage in durability. It should be noted, however, that in 1932 rot was found in the teak planking around *Victory's* bow.[49]

7.18. If wetting-up of the timber is expected, then the archaeologically significant material remaining in *Victory* is at risk; the aim stated in paragraph 1.1 cannot be met and an alternative approach to the ship's conservation is required.

Benefits to character and presentation

7.19. The use of teak as the timber of choice for hull planking has the potential to offer some advantages in the ship's presentation: The teak is likely to move a little less than oak, resulting in a reduced need to paint. Similarly, the increased durability of teak would reduce the urgency of repair works needed to address water ingress, should such occur. These advantages are countered by the likely need to paint the ship according to the maintenance regime required by the selected caulking system and the need to address any leaks in the hull in order to protect archaeologically significant material within the structure.

7.20. A clear understanding of how 'benefit' might be assessed requires careful consideration. Whilst minimising disruption to the ship's appearance by painting contractors and scaffolding may offer advantages in presentation, a strong counter-argument that such conservation work can be of interest to visitors and will play a key role in a visit to the ship over the course of the conservation project can be developed. Interpretation of the work necessary to protect an artefact such as *Victory* will be critical to delivering a successful conservation project; it is difficult to see why such a theme should be abandoned on completion of major work. Given the available evidence, the argument that an alternative timber, in this case teak, would bring particular benefits to the character and presentation of the ship appears equivocal at best.

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[45] P. Watts, 'Notes on the preservation of HMS Victory and her restoration to the Trafalgar condition'. *Mariner's Mirror*, Vol. 9 No. 2, 1923, p. 98.
[46] R. Stewart, Unicorn's *Extraordinary Roof*, Self-published, 2011, p. 18.
[47] LV50 was constructed with teak planking over oak frames in 1879. Both planking and frames were found to be in 'as new' condition in a recent condition survey. T. Nielsen & Co., *V2014.39,* p. 3.
[48] BM TRADA, *V2010.40*, p. 3.
[49] Bugler, p. 87.

8. Summary

8.1. It is clear that no timber species offers ideal characteristics that would make selection of appropriate timber straightforward.

8.2. The continued presence of deathwatch beetle poses a threat to the existing significant material in the ship. This population also poses a threat should oak be used in the ship's conservation and then allowed to wet up.

8.3. No timber species has durable sapwood.

8.4. Replacement on a like-for-like basis would suggest the use of oak. When measured against the criteria set forth in Policy 28 of the CMP:

- Oak has not proven to be defective or inefficient in the role.
- Oak is available in the correct quality and at an acceptable cost.
- Durability of oak, when maintained, has not been demonstrated to be measurably inferior compared to alternatives. There is little difference between the durability of oak and teak, when maintained, in UC3.
- No alternative timber appears to offer particular benefits to the character and presentation of the ship.

8.5. Accepting that application of the criteria set forth in Policy 28 does not result in the selection of an alternative timber choice, oak must be measured against Policy 26:

- Oak has a service life of 60 years in UC3 if coated, and significantly in excess of this if the coating is well maintained.
- Oak has a history of use in the proposed location and is known to perform well.
- Oak can be ethically sourced.
- Oak is appropriate for use on HMS Victory.

8.6. Selection of the most appropriate timber for the *Victory* project is clearly an issue of risk. If the timber is to be coated, that coating maintained, and plank seams/caulking maintained on a regular basis so as to prevent water ingress, oak is likely the most appropriate timber to select

8.7. However, should oak be exposed to occasional wetting and remain wet, it would be susceptible to fungal attack. Such fungal attack would render the oak susceptible to deathwatch beetle infestation.

8.8. Teak of DC1 is more durable than oak if exposed to decay and is also immune to deathwatch beetle attack.

8.9. Selection of an appropriate material thus becomes a question of how confident it is possible to be that the exterior envelope of the ship will be maintained completely weathertight. The selection of a caulking system is key in understanding the level of risk and developing a coating specification.

9. Recommendations

9.1. The presence of death watch beetle continues to pose a threat to the significant material in the ship and potentially poses a threat to new material introduced into the structure. A strategy for the reduction and eventual eradication of deathwatch beetle in HMS Victory should be developed.

9.2. Selection of an appropriate timber is part of a larger programme of work to develop the specification of a suitable planking system for the ship. Work to identify the appropriate construction method, fastening type and frequency, caulking, paying and paint finishes should continue in each of these categories before the final timber choice can be made.

9.3. In order for planning to move forward, however, it is recommended that oak be assumed as the candidate timber. On the information available, oak possesses clear advantages when considered against the requirements of the conservation management plan. If, on development of the planking specification, the risk of the timber wetting up is considered high a review of the scope of the project will be necessary - the archaeologically significant material remaining in *Victory* would be at risk; the aim stated in paragraph 1.1 cannot be met and an alternative approach to the ship's conservation will be required.

9.4. Use of baulk timber for large elements such as wale planking and beam ends would be historically accurate and this timber is readily available in the sizes and quantities required. Significant difficulties exist, however, in the seasoning of such timber and the risk of heart rot being present. The working group recommends, therefore, that for planning purposes, large elements should be assumed to be constructed from laminated oak.

9.5. It appears that 4" is the maximum thickness at which seasoned oak can be procured in a reasonable timeframe and without risk of heart rot. The working group recommends that further work be undertaken to establish what thicknesses of oak can be procured and are most appropriate for use in *Victory* in single thickness or as laminated elements, paying careful regard to the policies set forth in the conservation management plan.

9.6. On completion of these investigative studies, a trial of the proposed planking system should be undertaken, by constructing a test section, in order to evaluate the proposed materials and methods.

9.7. The test section of the proposed planking system should be used to inform the development of a risk assessment for the proposed planking system, including timber choice. Only on completion of a risk assessment can a fully informed decision be made on timber selection.

9.8. The proposed planking system and the accompanying proposed changes to the ship should be subject to a Heritage Impact Assessment in the course of planning works, in accordance with Policy 24 of the CMP.