Shipwright artistry: cultural transmission of British colonial ship design and construction during the eighteenth and nineteenth centuries

by

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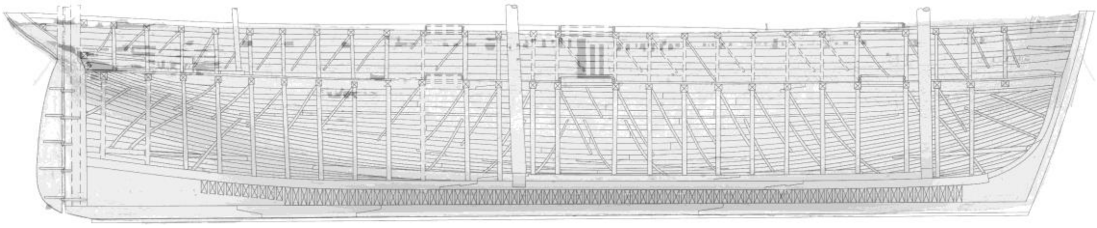

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Front cover image:

The starboard side of *Edwin Fox* overlaid on top of a port side construction drawing.

Table of Contents

List of Figures XII

List of tables XVIII

Summary XXI

Signed declaration XXII

Acknowledgements XXIII

Notes on text XXIV

Shortened forms XXIV

Timber drawing legend XXV

Dedication XXVI

Chapter 1. Introduction 1

1.1 Research question 3

1.2 Aims 3

1.3 Justification 4

1.4 Significance 5

1.5 Case studies 7

1.5.1 *Endeavour* (ex *Lord North*) (built 1771) 7

1.5.2 HMS *Buffalo* (ex *Hindostan*) (built 1813) 9

1.5.3 *Edwin Fox* (built 1853) 10

1.6 Methods 11

1.7 Permissions, ethics and consultations 14

1.8 Chapter outline 14

1.8.1 Chapter 2 Literature review 14

1.8.2 Chapter 3 Contextualising the past 15

1.8.3 Chapter 4 Methodological approaches 15

1.8.4 Chapters 5–7 *Endeavour*, HMS *Buffalo* and *Edwin Fox* results 15

1.8.5 Chapter 8 Discussion 15

1.8.6 Chapter 9 Conclusion 16

1.9 Conclusion 16

Chapter 2. Literature review 17

2.1 Introduction 17

2.2 Social learning 17

2.3 Cultural transmission 19

2.4 Behavioural archaeology 22

2.5 Behaviour modelling 24

2.6 Technology transfer 30

2.7 Structural innovation 31

2.8 Exploring process 33

2.8.1 Invention 34

2.8.2 Adoption 35

2.8.3 Design and type 36

2.9 Ship archaeology 40

2.10 Shipbuilding 45

2.11 Conclusions 49

Chapter 3. Contextualising the past 51

3.1 Defining terms 51

3.2 The Company 52

3.3 East Indiamen 53

3.4 Working with wood 55

3.5 The East Indiamen: Overview and background 60

3.6 English/British EIC archaeological ship studies 61

3.6.1 *Trial* (built c.1621) 61

3.6.2 *Avondster* (built c.1641) 62

3.6.3 *Griffin* (built 1748) 63

3.6.4 *Sydney Cove* (built c.1790s) 64

3.6.5 *Brunswick* (built 1792) 65

3.6.6 *Earl of Abergavenny* (built 1796) 66

3.6.7 *Java* (built 1811) 67

3.6.8 *Diana* (built 1812) 68

3.6.9 *Jhelum* (built 1849) **69**

3.7 Primary case studies **70**

3.7.1 *Endeavour* (ex *Lord North*) (built 1771) **71**

3.7.1.1 Historical background *71*

3.7.1.2 Significance and previous investigations *74*

3.7.1.3 Site formation *77*

3.7.2 HMS *Buffalo* (ex *Hindostan*) (built 1813) **83**

3.7.2.1 Historical background *83*

3.7.2.2 Significance and previous investigations *85*

3.7.2.3 Site formation *87*

3.7.3 *Edwin Fox* (built 1853) **88**

3.7.3.1 Historical background *88*

3.7.3.2 Significance and previous investigations *91*

3.7.3.3 Site formation *92*

3.8 Conclusion **94**

Chapter 4. Methodological approaches **96**

4.1 Archival research **97**

4.2 Ships lines **99**

4.3 Hull design calculations **100**

4.4 Disarticulated timbers from *Endeavour* and *Buffalo* **102**

4.4.1 National Museum of the Royal New Zealand Navy **102**

4.4.2 Southland Museum and Art Gallery Niho o te Taniwha **104**

4.4.3 Mercury Bay Museum **107**

4.4.4 Timber condition **107**

4.4.5 Timber recording **108**

4.5 Historically preserved hull recording, *Edwin Fox* **109**

4.5.1 Laser scanning **109**

4.5.2 3D digital modelling **111**

4.5.3 Profile construction drawing **113**

4.5.4 Midship construction drawing **113**

4.5.5 Keelson recording **118**

4.5.6 Ship timber catalogue **119**

4.6 Wood identification **120**

4.7 Dendrochronology **120**
4.7.1 Timber conversion **122**
4.8 Metal analysis **123**
4.8.1 Metal sheathing placement and stamp recording **125**
4.9 Fibre identification **126**
4.10 Organic analysis **127**
4.11 Photography **128**
4.12 Conclusions **128**
Chapter 5. *Endeavour* results **130**
5.1 Historical findings and hull design **130**
5.1.1 Hull lines **133**
5.1.2 Hull coefficients **134**
5.2 National Museum of the Royal New Zealand Navy **136**
5.2.1 Sacrificial timber sheathing **136**
5.2.2 Wood identification **138**
5.2.3 Metal analysis **138**
5.2.4 Fibre identification **138**
5.2.5 Organic analysis **138**
5.3 Southland Museum and Art Gallery Niho o te Taniwha **139**
5.3.1 Keel and false keel **141**
5.3.1.1 END_001 false keel fragment *141*
5.3.1.2 END_002 keel fragment *143*
5.3.1.3 END_003 keel fragment *144*
5.3.1.4 END_015 keel fragment *145*
5.3.1.5 END_017 keel fragment *147*
5.3.1.6 END_026 keel fragment *148*
5.3.2 Futtocks **150**
5.3.2.1 END_007 possible futtock *150*
5.3.2.2 END_013 possible futtock *151*
5.3.3 Garboard strake **153**
5.3.3.1 END_019 garboard strake *153*
5.3.4 Outer planking **154**
5.3.4.1 END_010 outer hull planking *154*

5.3.4.2 END_011 outer hull planking ... *155*
5.3.4.3 END_012 outer hull planking ... *156*
5.3.4.4 END_014 outer hull planking ... *157*
5.3.4.5 END_016 outer hull planking ... *158*
5.3.4.6 END_018 outer hull planking ... *159*
5.3.4.7 END_020 outer hull planking ... *160*
5.3.4.8 END_021 outer hull planking ... *161*
5.3.4.9 END_022 outer hull planking ... *162*
5.3.4.10 END_023 outer hull planking ... *163*
5.3.4.11 END_024 outer hull planking ... *164*
5.3.4.12 END_025 outer hull planking ... *165*
5.3.4.13 END_028 outer hull planking ... *167*
5.3.5 Sacrificial timber sheathing ... 168
5.3.5.1 END_004 Sacrificial timber sheathing ... *168*
5.3.5.2 END_005 (-A, -B and -C) Sacrificial timber sheathing ... *169*
5.3.5.3 END_029 Sacrificial timber sheathing ... *169*
5.3.5.4 END_030 Sacrificial timber sheathing ... *171*
5.3.6 Ceiling planking ... 173
5.3.6.1 END_027 Ceiling plank fragment ... *173*
5.3.7 Unidentified ... 174
5.3.7.1 END_006 unidentified timber ... *174*
5.3.7.2 END_008 unidentified timber ... *176*
5.3.7.3 END_009 unidentified timber ... *177*
5.3.7.4 END_031 unidentified timber ... *178*
5.3.7.5 END_032 unidentified timber ... *179*
5.3.7.6 END_033 unidentified timber ... *179*
5.3.7.7 END_034 unidentified timber ... *179*
5.3.7.8 END_039 unidentified timber ... *180*
5.3.8 Contextualising the timbers ... 180
5.3.9 Loose treenails ... 183
5.3.10 Wood identification ... 184
5.3.11 Metal analysis ... 185
5.3.11.1 END_036 sheathing tack ... *185*
5.3.11.2 END_037 sheathing tack ... *185*
5.3.11.3 END_038 keel bolt ... *186*
5.3.11.4 END_052 copper alloy fastener ... *188*
5.3.12 Fibre identification ... 190

5.3.12.1 END_035 caulking ... *190*
5.3.12.2 END_040 caulking ... *191*
5.3.13 Organic analysis ... 192

5.4 Summary ... 192

Chapter 6. HMS *Buffalo* results ... 193

6.1 Historical findings and hull design ... 193
6.1.1 Hull Lines ... 193
6.1.2 Hull coefficients ... 195

6.2 Mercury Bay Museum ... 195
6.2.1 False keel ... 196
6.2.1.1 BUF_014 false keel ... *196*
6.2.2 Futtock ... 197
6.2.2.1 BUF_015 futtock ... *197*
6.2.3 Outer plank ... 198
6.2.3.1 BUF_011 outer plank ... *198*
6.2.4 Sacrificial timber sheathing ... 199
6.2.4.1 BUF_001 sacrificial timber sheathing ... *199*
6.2.4.2 BUF_002 sacrificial timber sheathing ... *200*
6.2.4.3 BUF_003 sacrificial timber sheathing ... *201*
6.2.4.4 BUF_004 sacrificial timber sheathing ... *201*
6.2.4.5 BUF_005 sacrificial timber sheathing ... *203*
6.2.4.6 BUF_006 sacrificial timber sheathing ... *204*
6.2.4.7 BUF_007 sacrificial timber sheathing ... *205*
6.2.4.8 BUF_009 sacrificial timber sheathing ... *206*
6.2.5 Timber knee ... 207
6.2.5.1 BUF_013 timber knee ... *207*
6.2.6 Unidentified ... 210
6.2.6.1 BUF_008 unidentified timber ... *210*
6.2.6.2 BUF_010 unidentified timber ... *210*
6.2.6.3 BUF_012 unidentified timber ... *210*
6.2.7 Wood identification ... 211
6.2.8 Metal analysis ... 211
6.2.9 Metal stamps ... 212
6.2.10 Organic analysis ... 215
6.2.11 Previous archaeology ... 217

6.3 Summary **218**

Chapter 7. *Edwin Fox* results **219**

7.1 Historical findings and hull design **219**

7.1.1 Hull lines **219**

7.1.2 Hull coefficients **220**

7.2 Midship cross-section **222**

7.2.1 Timbers **226**

7.2.1.1 False keel *226*

7.2.1.2 Keel *227*

7.2.1.3 Floors and futtocks *228*

7. 2.1.4 Garboard strake *228*

7. 2.1.5 Hull planking layer one *229*

7. 2.1.6 Hull planking layer two *230*

7.2.1.7 Ceiling planking *231*

7.3 Metal sheathing **235**

7.4 Hull markings **238**

7.5 Graving piece **241**

7.6 Wood identification **241**

7.7 Dendrochronology **242**

7.8 Metal analysis **245**

7.9 Fibre identification **249**

7.10 Organic analysis **250**

7.11 Summary **250**

Chapter 8. Discussion **252**

8.1 Ships' hulls as a resource **252**

8.1.1 Disarticulated hull timbers **253**

8.1.1.1 Determining provenance *253*

8.1.2 Contextually preserved hulls **255**

8.2 The transmission of shipbuilding **255**

8.2.1 Hull shape and structural concept **256**

8.2.1.1 Summary *259*

8.2.2 Trees as a resource **260**
8.2.3 Assembling the hull **265**
8.2.3.1 Keel *266*
8.2.3.2 False keel *267*
8.2.3.3 Keelson *268*
8.2.3.4 Bilge keelson *269*
8.2.3.5 Futtocks *269*
8.2.3.6 Garboard Strake *271*
8.2.3.7 Outer hull planking *271*
8.2.3.8 Sacrificial outer planking *272*
8.2.3.9 Ceiling planking *274*
8.2.3.10 Summary *275*
8.2.4 Fasteners **276**
8.2.4.1 Treenails *276*
8.2.4.2 Treenail pegs *278*
8.2.4.3 Dumps *279*
8.2.4.4 Clinched bolts *280*
8.2.4.5 Iron nails *280*
8.2.4.6 Staples *281*
8.2.4.7 Keel bolts *282*
8.2.4.8 Copper alloy fasteners *283*
8.2.4.9 Sheathing tacks *283*
8.2.4.10 Summary *284*
8.2.5 Waterproofing technology **286**
8.2.5.1 Caulking *286*
8.2.5.2 Plank lining *287*
8.2.5.3 Pitch *287*
8.2.5.4 Summary *291*
8.2.6 Antifouling technologies **292**
8.3 Exploring process **296**
8.4 Assessing performance and behaviour **306**
8.4.1 Ship development model **308**
8.4.2 Summary **310**
8.5 Insights into shipwright behaviours **310**
8.6 Summary **313**

Chapter 9. Conclusions..315

9.1 Limitations 318

9.2 Future research...318

9.3 Significance..320

9.4 Conclusions 321

References..322

Glossary..338

Appendix 1 350

List of Figures

Figure 1. Location map of *Endeavour* abandoned in Facile Harbour, Aotearoa New Zealand. 8

Figure 2. Location map of Waihōpai Invercargill and Tamatea Dusky Sound, Aotearoa New Zealand. 9

Figure 3. Locations of the Mercury Bay Museum and the HMS *Buffalo* shipwreck, Whitianga, Aotearoa New Zealand. CBD (Central Business District). 10

Figure 4. Location map of the Edwin Fox Maritime Museum, Waitohi Picton, Aotearoa New Zealand. CBD (Central Business District). 11

Figure 5. Transmission processes affecting evolution (after Eerkens and Lipo 2007:246). 20

Figure 6. Cascade model encompassing CTS and life-history processes. 27

Figure 7. Chain model (after Mesoudi 2008:92). 29

Figure 8. The established trade routes of the Company during the eighteenth to nineteenth centuries (after Barrow 2017:XVI and XVII; Sutton 2000:25). 53

Figure 9. Line engraving on paper depicting Gabriel Snodgrass, 1719–1799, shipbuilder and surveyor to the East India Company (Drayton 1799). 56

Figure 10. Some of the forests north of the Malabar Coast (after Bulley 2000:xiv). 59

Figure 11. The '*Earl of Abergavenny*' East Indiaman, off Southsea. Oil on canvas by Thomas Luny (1759–1837), © British Library Board (Foster 59, c13161-18). 66

Figure 12. *Java* in Genoa for breaking up (1939) (https://gibraltar-intro.blogspot.com/2015/01/1811-java-triumph-of-skill-w.html). 68

Figure 13. *Jhelum*'s condition in 2006, Stanley Harbour, Falkland Islands (Courtesy of the Falkland Islands Museum and National Trust). 69

Figure 14. *Jhelum*'s condition when visited in 2016, showing only the aft section (Photograph: Nick Keenleyside). 70

Figure 15. Howland Great Dock near Deptford (Thomas Badeslade and Johannes Kip, 1707–1719?, PAH1988, National Maritime Museum, Greenwich). 71

Figure 16. An artist impression by Gainor Jackson of *Endeavour* hauled in close to shore (Courtesy of Toitū Otago Settlers Museum). 74

Figure 17. *Endeavour* marked with a leaning stake lodged in the ballast pile, when visited by Richard Henry between 1894–1900 (The University of Otago Library, The Hocken Collections / Uare Taoka o Hākena, Richard Henry Collection, 9029). 78

Figure 18. Evidence of salvage with a cut non-ferrous fastener on the *Endeavour* wreck site photographed 6 March 1984 (Photograph: Roger Grace, courtesy of Phyllida Cotton-Barker). 81
Figure 19. A non-ferrous fastener in *Endeavour*'s ship timbers photographed 6 March 1984 (Photograph: Roger Grace, courtesy of Phyllida Cotton-Barker). 81
Figure 20. Diver with *Endeavour* ship timbers photographed 6 March 1984 (Photograph: Roger Grace, courtesy of Phyllida Cotton-Barker). 82
Figure 21. A depiction of HMS *Buffalo* in 1836 by Young Bingham Hutchinson, Borrow Collection, Flinders University. 84
Figure 22. 'The storm', HMS *Buffalo* 1840 (Paul Deacon). 85
Figure 23. HMS *Buffalo* stem (left), description written on back of photograph (right): 'Portion of teak stem (side view), HMS *Buffalo*, wrecked near Whitianga, July 28 1840, salvaged Feb 2 1936'. (New Zealand Maritime Museum Hui Te Ananui a Tangaroa, 2003.14.2). 88
Figure 24. *Edwin Fox* c.1900 (Ship Edwin Fox at Picton (Daroux, Louis John, 1870–1948: Photographs of New Zealand and the Pacific. Ref: 1/1-039355- G. Alexander Turnbull Library, Wellington, New Zealand. /records/23160152). 90
Figure 25. The Edwin Fox Maritime Museum (centre) positioned along Waitohi Picton's foreshore (Photograph: Irene Vigiola Toña 2018). 91
Figure 26. The bow of *Edwin Fox*, prior to its refloating (Photograph: Ian McCleod c.1986). 93
Figure 27. *Edwin Fox* in dry dock at the Edwin Fox Maritime Museum, Waitohi Picton (2017). 94
Figure 28. Katarina Jerbić and Kurt Bennett photographing the Earthwatch *Edwin Fox* drawings (2017). 98
Figure 29. Block coefficient (A), prismatic coefficient (B), midship coefficient (C) diagrams (after Steffy 1994:255). 101
Figure 30. *Endeavour* timber fragment iPad recording screenshot. 103
Figure 31. The gallery area used for recording the timbers (Photograph: Kimberley Stephenson, April 2019). 105
Figure 32. *Endeavour* timbers placed in purpose-built storage shelves (Photograph: Kimberley Stephenson, June 2019). 107
Figure 33. Faro Focus^{s} 130 positioned at the bow of *Edwin Fox* (2016). 110
Figure 34. Station, buttock and waterlines intersecting the 3D digital *Edwin Fox* hull model. 113

Figure 35. Using a laser distance unit to measure the port side of the *Edwin Fox* hull (2017)....115
Figure 36. Katarina Jerbić and Matt Carter establishing the external baseline across the X axis at midships on the *Edwin Fox* hull (2017)....116
Figure 37. Establishing the internal midship lines inside the *Edwin Fox* hull (2017). 117
Figure 38. Baseline offset method for recording the keelson (2018)....118
Figure 39. Kurt Bennett extracting a core from the keelson aft of the main mast (2017)....121
Figure 40. Timber conversion types (after Hillam 2015). 122
Figure 41. Kurt Bennett cutting a metal sheathing sample from the *Edwin Fox* hull (Photograph: Katarina Jerbić, 2017). 123
Figure 42. Struers TegraPol-11 diamond polisher (Photograph: Wendy van Duivenvoorde, 2019). 124
Figure 43. FEG Quanta 450 with SDD EDS detector (Photograph: Wendy van Duivenvoorde, 2019). 125
Figure 44. An English East Indiaman c.1760s (after Chapman 2006:Pl. LI). 134
Figure 45. Lines plan of *Endeavour* based on Chapman's drawing. 135
Figure 46. Outer face of the *Endeavour* timber fragment recorded at the National Museum of the Royal New Zealand Navy....136
Figure 47. Sacrificial timber (2006.1631.14; SYA 0014) held in collection at the National Museum of the Royal New Zealand Navy (2018). 137
Figure 48. Woven matting recorded on *Endeavour*'s sacrificial timber fragment (2006.1631.14; SYA 0014) held in collection at the National Museum of the Royal New Zealand Navy (thread = 1 mm)....137
Figure 49. END_001 false keel and END_002 keel fragment drawing....142
Figure 50. END_003 keel fragment drawing....145
Figure 51. END_015 keel fragment drawing....146
Figure 52. END_017 keel fragment drawing....148
Figure 53. END_026 keel fragment drawing....150
Figure 54. END_007 futtock drawing....151
Figure 55. END_013 futtock drawing....152
Figure 56. END_019 garboard strake drawing. 153
Figure 57. END_010 outer hull plank fragment drawing. 154
Figure 58. END_011 outer hull plank fragment drawing. 156
Figure 59. END_012 outer hull plank fragment drawing. 157
Figure 60. END_014 outer hull plank fragment drawing. 158
Figure 61. END_016 outer hull plank fragment drawing. 159

Figure 62. END_018 outer hull plank fragment drawing. 160
Figure 63. END_020 outer hull plank fragment drawing. 161
Figure 64. END_021 outer hull plank fragment drawing. 162
Figure 65. END_022 outer hull plank fragment drawing. 163
Figure 66. END_023 outer hull plank fragment drawing. 164
Figure 67. END_024 outer hull plank fragment drawing. 165
Figure 68. END_025 outer hull plank fragment drawing. 166
Figure 69. END_028 outer hull plank fragment drawing. 167
Figure 70. END_004 sacrificial timber and metal sheathing drawing. 168
Figure 71. END_029 sacrificial timber drawing. 171
Figure 72. END_030 sacrificial timber and metal sheathing drawing. 172
Figure 73. END_027 ceiling plank fragment drawing. 174
Figure 74. END_006 unidentified timber fragment drawing. 175
Figure 75. END_008 unidentified timber fragment drawing. 177
Figure 76. END_009 unidentified timber fragment drawing. 178
Figure 77. *Endeavour* keel timbers END_001 and END_002 (green), END_003 (blue), END_015 (yellow) and END_026 (red) digitally reassembled. 181
Figure 78. Reconstructed keel (blue) with the garboard strake END_019 (orange) positioned (top image) and a full colour render showing the keel assembly (bottom image). 181
Figure 79. Keel assembly overlayed onto the *Endeavour* lines plan. 182
Figure 80. Loose treenail (END_041) from the *Endeavour* collection, Southland Museum and Art Gallery Niho o Te Taniwha (Photograph: Kimberley Stephenson, 2019). 184
Figure 81. Sheathing tacks END_036 (far right), END_037 (centre), from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha (Photograph: Kimberley Stephenson, 2019). 185
Figure 82. Loose keel bolt (END_038) drawing, from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha. 187
Figure 83. Copper alloy fastener (END_052) from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha (Photograph: Kimberley Stephenson, 2019). 188
Figure 84. A possible piece of caulking (END_035) sampled from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha (Photograph: Kimberley Stephenson, 2019). 190

Figure 85. Loose piece of caulking (END_040) sampled from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha (Photograph: Kimberley Stephenson, 2019). 191
Figure 86. HMS *Buffalo* ship's lines plan. 194
Figure 87. BUF_014 false keel timber fragment and metal sheathing drawing. 197
Figure 88. BUF_015 futtock timber fragment drawing. 198
Figure 89. BUF_001 sacrificial timber sheathing fragment drawing. 199
Figure 90. BUF_002 sacrificial timber sheathing fragment drawing. 200
Figure 91. BUF_003 sacrificial timber sheathing fragment drawing. 201
Figure 92. BUF_004 sacrificial timber sheathing fragment drawing. 202
Figure 93. BUF_005 sacrificial timber sheathing fragment drawing. 203
Figure 94. Broad arrow stamp recorded on BUF_005 sacrificial timber sheathing, Mercury Bay HMS *Buffalo* timber collection. 204
Figure 95. BUF_006 sacrificial timber sheathing fragment drawing. 205
Figure 96. BUF_007 sacrificial timber sheathing fragment drawing. 206
Figure 97. BUF_009 sacrificial timber sheathing fragment drawing. 207
Figure 98. BUF_013 timber knee drawing. 209
Figure 99. (A) *Buffalo* sheathing stamp 008, (B) *Buffalo* sheathing stamp 009, (C) *Buffalo* sheathing stamp 010, (D) *Buffalo* sheathing stamp 011. 215
Figure 100. *Edwin Fox* ship's lines plan. 221
Figure 101. *Edwin Fox* midship cross-section labelled with timber components. 224
Figure 102. Longitudinal cross-section showing the port side and internally recorded timbers. 225
Figure 103. Aft section of the false keel attached to the main keel of *Edwin Fox*, facing port side. 227
Figure 104. Metal sheathing folded in the forward join of the false keel. 227
Figure 105. The outer most layer of hull planking on *Edwin Fox*, port side, facing forward. Midships is located in the area where the planks are positioned most vertical. Red arrow indicates approx. midship line. 231
Figure 106. Ceiling planking inside the hull of *Edwin Fox*, port side, facing forward. The main mast is located to the far right. 233
Figure 107. Damage caused by tongs (support poles) (Photograph: Matt Carter, April 2017). 235
Figure 108. Arrangement of Muntz sheathing on the starboard bow of *Edwin Fox*. Note: where the tacks are not depicted is because of surface corrosion. Not to scale. 236
Figure 109. Muntz stamp recorded on the *Edwin Fox* hull. 237

Figure 110. Site plan of markings in relation to *Edwin Fox*’s keelson, rider keelson, forward and main mast steps. 238
Figure 111. Carved letter, number or symbol on *Edwin Fox*’s main mast step. 239
Figure 112. ‘VI’ marking on the sixth stanchion, aft of the forward main mast. 240
Figure 113. Graving piece, portside, aft of forward mast. 241
Figure 114. Dendrochronology core samples EFX007A (left), EFX007B (centre) extracted from *Edwin Fox*’s keel and EFX010 (right) extracted from the keelson. 244
Figure 115. CS-008 set in resin before polishing (Photograph: Wendy van Duivenvoorde, 2020). 247
Figure 116. CS-008 shavings under microscope (Photograph: Wendy van Duivenvoorde, 2020). 248
Figure 117. Possible circular saw marks recorded on END_021 with detailed magnified. 263
Figure 118. Box joint schematic. 268
Figure 119. Recorded treenail types. 277
Figure 120. Triangle treenail wedges (centre) on the second planking layer on *Edwin Fox*, port side (2017). 278
Figure 121. Dumps used for fastening ceiling plank CS5 in the *Edwin Fox* hull (2020). 280
Figure 122. *Endeavour* staple held in collection at the Southland Museum and Art Gallery Niho o te Taniwha (after photograph: Kimberley Stephenson, April 2019). 281
Figure 123. HMS *Buffalo* staple on display in the Mercury Bay Museum. The bend is probably caused by modern salvage processes. 282
Figure 124. *Endeavour* (left), HMS *Buffalo* (centre) and *Edwin Fox* (right) sheathing tacks. 284
Figure 125. Ship’s plan of *True Briton* reproduced for scale modelling (Harold A. Underhill, Brown, Son and Ferguson Ltd). 300
Figure 126. A model of *Seringapatam* (1837) ([SLR0763] © National Maritime Museum, London, Greenwich, London with permission). 301
Figure 127. *Griffin*’s keel as recorded in situ (after Goddio and Guyot de Saint Michel 1999:61 and 62). 302
Figure 128. BEIC bottom plank thicknesses versus registered ship tonnage between the mid to late eighteenth century. Data extracted from (Snodgrass 1797a:63–74). 303
Figure 129. S-curve ship development model. 309

List of tables

Table 1. Timber condition grading system used for recording. 108
Table 2. Scantling dimensions as recorded for *Lord North* (*Endeavour*) ([BL] IOR/L/MAR/C/529:20). 130
Table 3. *Lord North* undergoing extensive repairs and partial rebuild between 1785 and 1786 ([BL] L.R.264.b.3:Appendix 575, 612, 641, 653, 661, 702, 739, 762, 778 and 783, 824). 133
Table 4. Fibre sample from the *Endeavour* timber fragment, National Museum of the Royal New Zealand Navy. 138
Table 5. Pitch results from the *Endeavour* sacrificial timber fragment (2006.1631.14; SYA 0014). 139
Table 6. Summarised *Endeavour* timber dimensions, Southland Museum and Art Gallery Niho o te Taniwha. 141
Table 7. Loose treenails recorded in the *Endeavour* ship collection, Southland Museum and Art Gallery Niho o te Taniwha. 183
Table 8. Wood samples from the Southland Museum *Endeavour* ship timber collection. 184
Table 9. Metal samples collected from the Southland Museum and Art Gallery Niho o te Taniwha *Endeavour* ship timber collection. 188
Table 10. *Endeavour*'s sheathing and tacks elemental composition results. 189
Table 11. Fibre samples from the Southland Museum *Endeavour* ship timber collection. 191
Table 12. Scantling dimensions as recorded for *Hindostan* (HMS *Buffalo*). 193
Table 13. Summarised HMS *Buffalo* timber dimensions, Mercury Bay Museum. 196
Table 14. Timber identification for HMS *Buffalo* ship timbers. 211
Table 15. Metal samples collected from the Mercury Bay Museum ship timber collection. 211
Table 16. HMS *Buffalo* sheathing elemental composition results. 212
Table 17. Sheathing summary. 213
Table 18. Pitch results from HMS *Buffalo* timbers. 216
Table 19. The results from the 1986 excavation. 217
Table 20. Scantlings as historically recorded for *Edwin Fox*. 219
Table 21. Recorded dimensions of hull planking, layer one, *Edwin Fox*. 229
Table 22. Recorded dimensions of hull planking, layer two, *Edwin Fox*. 231

Table 23. Recorded dimensions of the ceiling planking, below the lower deck, *Edwin Fox*. 234
Table 24. Recorded dimensions of the ceiling planking between the upper and lower decks, *Edwin Fox*. 234
Table 25. *Edwin Fox* wood identification. 242
Table 26. Details of dendrochronology cores collected from *Edwin Fox*. 245
Table 27. A summary of the samples collected from the *Edwin Fox* hull sheathing. 246
Table 28. *Edwin Fox* hull sheathing elemental composition results. 246
Table 29. *Edwin Fox* elemental composition of white spots in the Muntz metal sheathing. 246
Table 30. *Edwin Fox* elemental composition of the sheathing tacks. 246
Table 31. *Edwin Fox* elemental composition of bolt. 248
Table 32. Fibre samples from *Edwin Fox*. 249
Table 33. Fibres identified in the organic compound layer between the metal sheathing and outer planking layer on *Edwin Fox*. 249
Table 34. Pitch results from the *Edwin Fox* hull. 250
Table 35. Summarised coefficient results for the three case studies. 257
Table 36. L:B ratio and vessel design classification (after Mckee 1983). 258
Table 37. *Endeavour*, HMS *Buffalo* and *Edwin Fox* hull shape classified. 258
Table 38. Wood used in *Endeavour*, HMS *Buffalo* and *Edwin Fox* (presented with both scientific and common names). 261
Table 39. Evidence of tool marks recoded on *Endeavour*, HMS *Buffalo* and *Edwin Fox*. 263
Table 40. Summarised recorded keel dimensions of *Endeavour*, *Buffalo* and *Edwin Fox*. 266
Table 41. Recorded false keel dimensions. 267
Table 42. Futtock dimensions measured on *Endeavour*, HMS *Buffalo* and *Edwin Fox*. 270
Table 43. Average dimensions recorded for outer planking. 271
Table 44. Recorded dimensions of sacrificial sheathing. 273
Table 45. Recorded ceiling planking dimensions. 274
Table 46. Treenail diameters summarised for *Endeavour*, HMS *Buffalo* and *Edwin Fox*. 276
Table 47. Sheathing tack dimensions. 284
Table 48. Hull sheathing metal composition and sheet dimensions. 293
Table 49. Eighteenth and nineteenth century British merchant ship comparison using archaeological and historical data (presented in metric). 297

Table 50. Performance characteristics for antifouling technologies. 308

Summary

Previous ship studies often grouped vessels into typologies to demonstrate a linear progression of development. This investigation of *Endeavour* (built 1771), HMS *Buffalo* (built 1813) and *Edwin Fox* (built 1853) employs a thematic approach to demonstrate that hull development is influenced by the cross-temporal transmission of knowledge and technologies. This research addresses how the investigation of design and construction of British East India colonial ships inform us of ship manufacture during the late-eighteenth and early to mid-nineteenth centuries. A review of archaeological, archival, material analyses, material identification and dendrochronology is used to answer several lines of enquiry. These include identifying external factors affecting information exchange between shipbuilding industries; interpreting design and construction changes over time using material evidence; exploring innovation and adaptation to new technologies; assessing properties of local ship timbers; and developing a framework to understand ship development. Finally, this study discusses the social, political, economic, cultural and environmental factors that influenced ship development and the exchange of information between shipwrights and is used to more fully develop British colonial and Indian ship studies.

This research is significant to the discipline of nautical archaeology and to the advancement of several nations’ shared maritime heritage. It contributes to understanding colonial ship construction and reveals meaningful insights into resource selection, technological changes and shipwright behaviours during the eighteenth and nineteenth centuries. The ships *Endeavour,* HMS *Buffalo* and *Edwin Fox* are intertwined with several countries and represent multi-faceted historical records that resulted from cultural transmission. Furthermore, this thesis is significant because it investigates for the first time these vessels located within Aotearoa New Zealand that are threatened by natural and cultural site formation processes.

Signed declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Kurt Bennett

February 2021

He mihi aroha

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Finally, I am forever grateful for my parents' support.

Notes on text

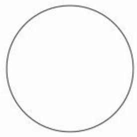
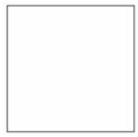
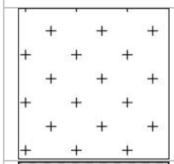
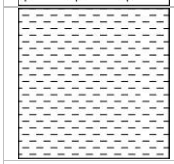
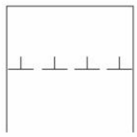
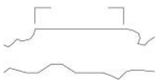
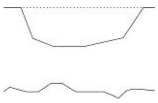
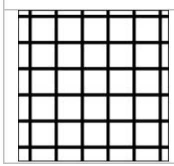
This thesis applies the April 2020 *Australian Archaeology* style guide. This thesis uses Australian spelling and utilises the online Macquarie Dictionary (https://www.macquariedictionary.com.au). Footnotes are used sparingly in this thesis to provide additional explanation to the main text. Ship names are italicised. AD (*Annō Dominī*) is used for dates. Ship dimensions extracted from historical sources are presented in imperial notation first, followed by metric conversions. For the purposes of discussion, metric conversions are used in combination with the contemporary metric recordings. Photographers are acknowledged in all figure captions for their contribution—where no credit is included the image is courtesy of the author. A glossary of ship terminology is provided after the refence list.

The three primary case studies, *Endeavour*, HMS *Buffalo* and *Edwin Fox*, are all located in Aotearoa New Zealand and have historical ties to the island nation's maritime heritage. This text acknowledges Māori place names existed in Aotearoa before European colonisation and continue to the present. Both Te Reo Māori and English are recognised official languages in Aotearoa New Zealand and are used in this thesis to reflect this. Mick de Ruyter proofread this thesis. No other professional editing services were used.

Shortened forms

EIC	East India Company	£	Pounds sterling
HEIC	Honorable East India Company	d.	Penny sterling
BEIC	British East India Company		
		Lbs	Pounds
m	Metres	Kg	Kilograms
cm	Centimetres		
mm	Millimetres	C	Carbon
		Cu	Copper
ft	Feet	Fe	Iron
in	Inches	Pb	Lead
		Sn	Tin
°C	Degrees Celsius	Zn	Zinc

Timber drawing legend

	Empty round hole
	Empty square hole
	Treenail
	Treenail with wedge
	Metal sheathing
	Pitch
	Round metal fastener
	Square metal fastener
	Bevel edge
	Original edge
	Missing edge
	Fabric

‘Maaate!’

Finn Henry Mrkusic Lowery

1990–2019

Chapter 1. Introduction

> To understand the past, archaeologists must find ways of making material remains speak, speak reliably, and speak in a language we can understand (Peregrine 2001:1).

Nautical archaeology has led to many studies that have revealed the intricacies of vessel structures by recognising that they were some of the most complex artefacts created by humankind (Maarleveld 1995:3). The construction of these vessels involved technical skill and knowledge executed from conceptualisation to reality (Maarleveld 1995:3–4). By studying the finer details, such as material choice, tool variation and technical knowledge, archaeologists reveal insights into the human behaviours linked with those who envisioned and constructed the vessels (Maarleveld 1995:4). This study incorporates three case studies of ships used in the global British merchant trade during the late-eighteenth to mid-nineteenth centuries. The detailed investigation of *Endeavour,* built in 1771, sank 1795; HMS *Buffalo,* built in 1813, shipwrecked 1840; and *Edwin Fox,* built in 1853 and purchased by the Edwin Fox Preservation Society in 1965, provides a better understanding of how their construction was influenced by local environments and technological innovations and other external political, social and economic factors.

In 1601, the first voyage for the Honourable East India Company (HEIC) sailed from England to India and to Southeast Asia, returning in 1603 (Sutton 2000:155). This voyage brought back spices and items to their respective domestic markets—continuing this trade into nineteenth-century Britain. The ships used in this trade were vital to the Company's success. First, the Company required its ships to be designed with a combination of merchant features and naval armament. The ships and crew had to be able to protect themselves against enemy vessels and carry as much cargo as possible to ensure profitability. During the eighteenth century, Britain's domestic timber stocks for shipbuilding began to diminish and supply was unable to keep up with the pace of shipbuilding. Furthermore, Britain began invading and colonising foreign countries and, as a result, secured additional shipbuilding resources. Over the centuries, ship design and construction elements were adapting to changing political, social, environmental and economic factors.

HEIC ships have received little archaeological attention in relation to their design and construction modifications over time. In the past four decades, a number of archaeological sites of English East Indiaman have received only individual rather than collective analysis (see Bouquet et al. 1990; Cumming and Carter 1990; Daggett et al. 1990; Forrest and Gribble 2002; Green 1977). These site inspections and excavations have been limited to site identification and the analysis of associated artefacts as opposed to detailed hull studies. This is because of either a particularist research approach that focussed on ship cargoes, or the lack of preserved timber hull remains available for recording (Bass 2011; Gould 1983).

Theme-based research offers the opportunity to conceptualise the ship and its components. The application of thematic studies supports vessel research by moving beyond descriptive and functional analysis to involving multi-disciplinary investigations (Richards 2006:52). Thematic research challenges the previous notion that a shipwreck is a time-capsule and argues for ship studies to be viewed through a diachronic lens—assessing and redefining historical processes (Richards 2012:52). This thesis explores three case studies using a multi-disciplinary approach to examine changes in British merchant ship design and construction technologies over time.

Archaeological research that focuses on design and construction adaptations specific to English East Indiaman has been absent from the corpus of ship studies. Sally May (1986:17) identified this research gap in the 1980s and enquired ‘to what extent Indian and European ship designs, technology and methods of construction were married?’ This PhD research addresses this question and employs historical research, ship timber recording, material analysis, wood identification and dendrochronology to extract data from ships’ timbers to better understand British East India Company (BEIC) shipbuilding practices. This research also contributes to theme-based nautical archaeological studies. It investigates whether structural features and construction technology were adapted by shipwrights employed to construct Company ships during the eighteenth and nineteenth centuries. Thijs Maarleveld (1995:6) argued that studying ship components in their own right and structuring data by groupings or classifications makes it possible to trace variability at different levels, including size, capacity, general hull-form, function, building sequence, raw materials, conversion techniques and fastening techniques.

Ship timbers from *Endeavour* and HMS *Buffalo*, and the historically preserved hull of *Edwin Fox*, present a significant opportunity to record design and construction elements from British global merchant ships. This study applies a behavioural framework to assess the transfer of technology and knowledge across time and space. This thesis contributes to our understanding of British colonial merchant shipbuilding practices during the later years of the East India Company. Furthermore, this research complements traditional nautical archaeology approaches to investigating ships and produces new data about ship design and construction adaptations, which enables a fuller understanding about shipwright practices and knowledge.

1.1 Research question

This study addresses the following research questions: How does the cultural transmission of design and construction practices of British East India Company ships contribute to our understanding of ship manufacture during the eighteenth and nineteenth centuries; and to what extent did social, political, economic, cultural and environmental factors influence ship development and the exchange of information between shipwrights?

1.2 Aims

This thesis aims to:

- identify external factors affecting information exchange between shipbuilding industries, including economic, political, social, cultural and environmental factors;
- use material evidence to produce quantitative data to interpret design and construction changes over time;
- determine how existing knowledge was applied to new timber resources by shipwrights and to consider how local timber resources influenced the way shipwrights of British shipyards in India constructed vessels;

- determine how innovation and adaptation to new technologies contributed to the advancement of ship design;
- develop a framework to understand ship development and to contribute to ship evolution studies; and
- confirm the historical record of *Endeavour* and to undertake the first comprehensive recording of *Endeavour's* ship timbers in museum collections.

1.3 Justification

Research into eighteenth- and nineteenth-century BEIC ships contributes to our understanding of how colonial shipbuilding design and construction practices developed. BEIC is used in this thesis to differentiate from other names that refence the Company. These are described in section 3.1 Defining terms. This research employs the theoretical framework of cultural transmission and Michael Schiffer's (2010:128–134) technology differentiation to investigate the transfer of British shipwright knowledge and considers how this was applied to shipbuilding practices. As a result, this research moves away from traditional nautical archaeological approaches of analysing ship typology and sets out to examine ship construction themes to understand the behaviours of shipwrights and how external social, political, economic, cultural and environmental factors influenced their decisions. Understanding the transmission of shipwright behaviours expands our knowledge of why and how ship design and construction practices changed over time, as well as provides new interpretations of the factors that influenced these changes.

Existing literature relating to the vessels employed in the Company's service is limited to historical archival research or the investigation of individual archaeological shipwreck sites and objects. This research will combine historical records with known archaeological sites to extract cultural information from ships' timbers pertaining to shipwrights' construction behaviours (see Creasman 2010). Specifically, this research will examine for the first time the structural features of *Endeavour* (1771), HMS *Buffalo* (1813) and *Edwin Fox* (1853) to identify tangible evidence relating to design and construction adaptations. By comparing historical

sources and archaeological remains, this research contributes to our understanding of British ship development.
Dendrochronology is employed in this research to provide independent data about timbers as a shipbuilding resource. The study of tree ring data has allowed for specific investigation of timber pairing and an assessment of tree age for the keel. Inferences made from this research contribute to our understanding in two ways. First, new knowledge about how British shipwrights selected, prepared and used their timber resources for ship construction are presented. Second, timber resource data collected during this project provides evidence for future research on historic environmental impacts. As a result, this combination of historical, archaeological and scientific methodologies further enriches our knowledge about British colonial shipbuilding and timber procurement.

1.4 Significance

In a global context, this research is significant because BEIC vessels sailed to many different territorial lands and waters around the world. By understanding this spatial element, the influence of the BEIC seafaring ability, trade and colonisation can be placed into context. Understanding where the Company's ships sailed to and from, and for what reasons assigns international significance to the Company and its ships. Therefore, the significance relating to the study of these ships extends beyond the timber hull structure, to understanding the impacts that colonisation had on existing nations and occupied lands outside of Britain.

Internationally, this project is significant because it investigates, in detail, the last surviving mid-nineteenth-century East India trading vessel, *Edwin Fox*. The vessel has historical connections with India, Britain, Crimea, Australia and Aotearoa New Zealand and was used for a variety of purposes including shipping general cargo, troop carrying, transferring convicts, transporting immigrants and warehousing for the meat industry (1853–c.1900).

The economic importance of exhibiting an historic ship at the Edwin Fox Maritime Museum is also recognised locally to the town of Picton and to the wider Marlborough region. *Edwin Fox*, however, is currently under threat from environmental processes (Bennett 2018). The hull sits in dry dock supported by timber tongs and is therefore exposed to seismic activity. Earthquakes experienced in 2016 and continuing aftershocks felt in the Marlborough region threatened to destroy the vessel (Bennett and McLeod 2018). Due to the vessel's exposure to the unpredictable nature of earthquakes, it is at risk of being damaged beyond repair—resulting in the loss of important archaeological information and economic input for Picton. As such, this study of *Edwin Fox* contributes a detailed survey of the vessel for the museum's records.

Both *Endeavour* and HMS *Buffalo* are registered archaeological sites in Aotearoa New Zealand. The *Heritage New Zealand Pouhere Taonga Act 2014* defines an archaeological site as:

> (a) any place in New Zealand, including any building or structure (or part of a building or structure), that—
>
> (i) was associated with human activity that occurred before 1900 or is the site of the wreck of any vessel where the wreck occurred before 1900; and
>
> (ii) provides or may provide, through investigation by archaeological methods, evidence relating to the history of New Zealand; and
>
> (b) includes a site for which a declaration is made under section 43(1).

Thus, *Endeavour* is recorded as site number S156/9 and HMS *Buffalo* is listed as site number T11/562 in ArchSite[1], the national archaeological database. *Edwin Fox* is excluded from protection under this Act as no shipwrecking event occurred. The ship, therefore, survives as an historic structure.

This PhD research also represents the first archaeological recording of *Endeavour's* timber remains. This ship is the oldest known European vessel to have sunk in Aotearoa New Zealand (1795), a premise challenged by Palmer et al. (2014), but later heavily refuted (van Duivenvoorde 2014; Wildeman 2014). The study of the ship's timbers is extremely important because while it is a nationally historically

---

[1] Archsite is a national online database for recorded archaeological sites in Aotearoa New Zealand (www.archsite.org.nz).

significant site, a complete heritage assessment has not been undertaken including considerations of site condition and detailed recordings of the existing timbers. This study adds to our understanding of Aotearoa’s New Zealand’s oldest known European vessel and provides Heritage New Zealand Pouhere Taonga with an accurate record of its material remains located in museums. Thus, new information can be included in future policy decision making surrounding protection and preservation of the shipwreck and its associated materials.

The significance to the discipline of archaeology is twofold. First, the archaeological recording of *Edwin Fox* documents the last most complete surviving example of a mid-nineteenth-century colonial built East India merchant vessel. Information gleaned from this investigation contributes to future research avenues, involving other European East India Companies’ merchant fleets and to our global understanding of colonial shipbuilding practices. Second, this research builds upon the application of cultural transmission theory and technology differentiation in nautical archaeological research (Eerkens and Lipo 2007; Schiffer 2010:128–133). Specifically, this investigation of BEIC ship development identifies social, political, economic and environmental factors that influenced ship design and construction during the eighteenth and nineteenth centuries. This is important because these factors that altered ship construction reflect the development of global shipping and the trajectory of ships as objects that participated in colonial expansion. Furthermore, this study applies a new theoretical lens to the interpretation of ship construction in the discipline of nautical archaeology.

1.5 Case studies

1.5.1 *Endeavour* (ex *Lord North*) (built 1771)

Existing publications describe *Endeavour* as constructed c.1724/1725, measuring 180 ft (60 m) in length by 32 ft (10.5 m) in breadth and an estimated tonnage of 700/800 tons (Boocock and Kenderdine 1992:2; Locker-Lampson and Francis 1979:35). The construction incorporated a mixture of English oak and East Indian teak fastened together with wooden treenails and pure copper (Ingram 1977:2). These recorded hull dimensions are nevertheless inconsistent with those of other ships of the same age (see Sutton 2000:150–153).

This PhD research traced *Endeavour*'s history and found the original construction date to be 1771 (IOR/L/MAR/C/529:20). Historical archives also revealed the vessel was constructed in Howland Dock, London, although there were no detailed descriptions of materials used in its assembly (IOR/L/MAR/C/529:20). The original hull dimensions were recorded as 138 ft (42.06 m) in length by 36 ft (10.97 m) in breadth and a measured tonnage of 777 tons (IOR/L/MAR/C/529:20). Therefore, this research addresses discrepancies between the historical record and existing publications.

In 1795, after leaking on a voyage from Australia, the ship sank and was abandoned in Facile Harbour, Tamatea Dusky Sound, Aotearoa New Zealand (Figure 1) (Locker-Lampson and Francis 1979:35). Since its abandonment, visitors to the site removed materials from the ship site with the exposed hull structure gradually disappearing below the water line (Ingram 1977:2). In the 1970s, a substantial collection of hull timbers from the wreck site were salvaged by members of the public and are now stored at the Southland Museum and Art Gallery Niho o te Taniwha, Waihōpai Invercargill (Figure 2). These salvaged timbers were used for this study, in addition to other *Endeavour* materials held by the National Museum of the Royal New Zealand Navy (Navy Museum).

Figure 1. Location map of *Endeavour* abandoned in Facile Harbour, Aotearoa New Zealand.

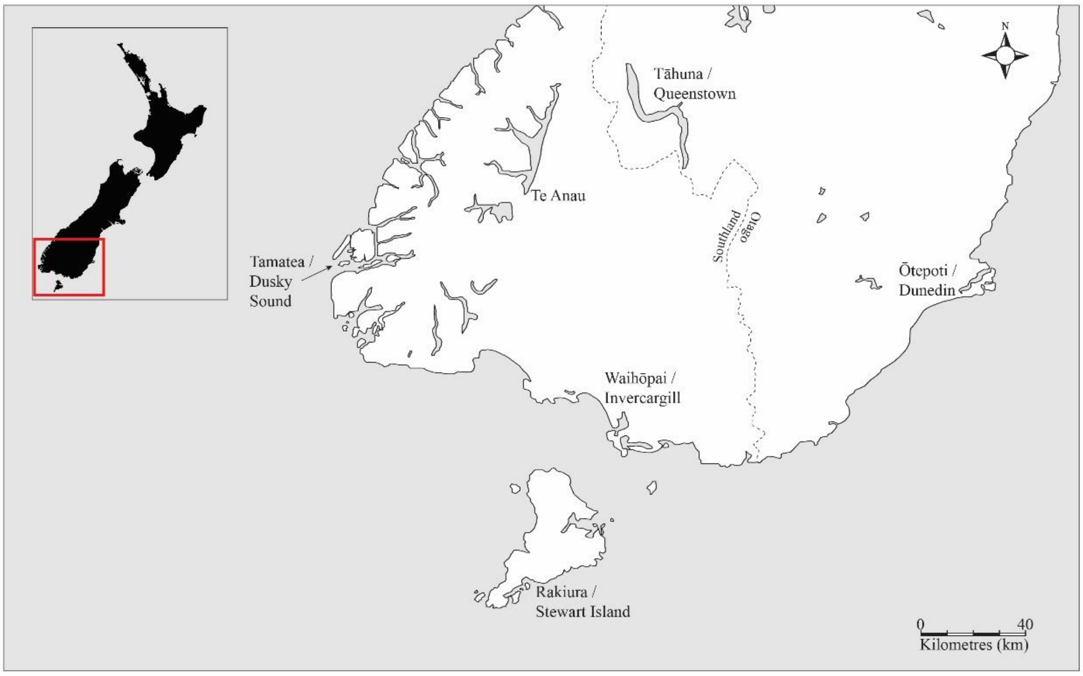


Figure 2. Location map of Waihōpai Invercargill and Tamatea Dusky Sound, Aotearoa New Zealand.

1.5.2 HMS *Buffalo* (ex *Hindostan*) (built 1813)

The ship *Hindostan*, constructed in Sulkea, India and launched in 1813 measured 120 ft (36.6 m) in length (Ingram et al. 2007:28). After the ship's first voyage to Britain, it was acquired by the British Admiralty and commissioned as HMS *Buffalo*. Over its life, the vessel was repurposed as a store ship, a quarantine ship, a merchant ship, a convict ship and an immigrant ship. The vessel was wrecked in 1840 in Whitianga while loading timber spars (Figure 3). Ship timbers from the wreckage are occasionally recovered from the local beach during storm events and the Mercury Bay Museum contains a *Buffalo* timber collection.

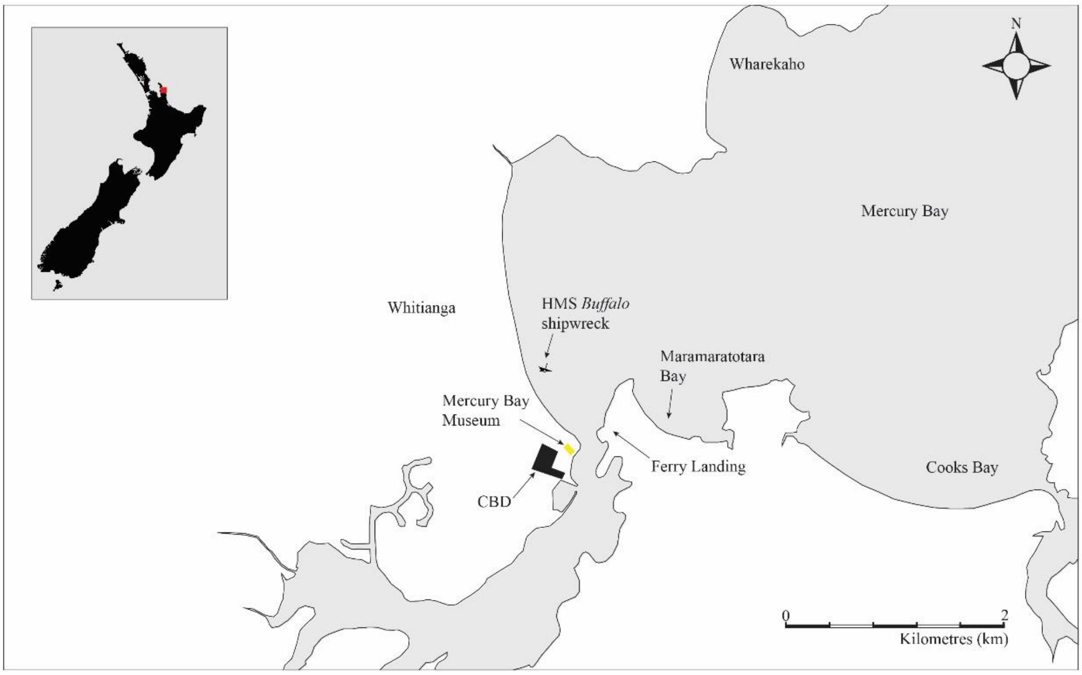


Figure 3. Locations of the Mercury Bay Museum and the HMS *Buffalo* shipwreck, Whitianga, Aotearoa New Zealand. CBD (Central Business District).

1.5.3 *Edwin Fox* (built 1853)

In 1853, the BEIC commissioned the construction of *Edwin Fox* in a shipyard in Bengal, India, measuring 157 ft (47.85 m) in length overall (Schauffelen 2005:254). Originally, the ship had a full rig, but its rig was later changed to a barque in 1878 (Locker-Lampson and Francis 1979:30). Shipwrights constructed the hull using Indian teak and sal timber and sheathed it in Muntz metal below the waterline (Mortiboy et al. 2003b:340). The ship's sailing career involved transporting troops during the Crimean war, transporting convicts from England to Western Australia and between 1873 to 1885, immigrants to Aotearoa New Zealand (Locker-Lampson and Francis 1979:30). Shortly after the final voyage to Aotearoa New Zealand, the ship was converted into a refrigeration meat store and moored in ports around the country. Finally, the ship ended up in Waitohi Picton and was used as a coal hulk (Locker-Lampson and Francis 1979:30).

In the 1960s, a local preservation society purchased the ship and preserved it at the Edwin Fox Maritime Museum (Figure 4). *Edwin Fox* is the last surviving intact hull of a British East Indiaman, worldwide. The ship forms the main exhibit for the Edwin Fox Maritime Museum and is accessible to the public for viewing (including the underside and inside of the hull).

Figure 4. Location map of the Edwin Fox Maritime Museum, Waitohi Picton, Aotearoa New Zealand. CBD (Central Business District).

1.6 Methods

Archival material provided existing knowledge of how shipwrights constructed East Indiamen and understanding the changes in environment between Britain and India. The researcher accessed archival material at several locations, including the National Archives, London, British Online Archives (https://www.britishonlinearchives.co.uk), British Library [BL], Caird Library, Greenwich National Maritime Museum, New Zealand Maritime Museum Hui te Ananui A Tangaroa and the Marlborough Museum Archives.

Different methodological approaches were employed for this study due to the various types of materials used in the vessels' construction. Disarticulated timber remains from *Endeavour* and HMS *Buffalo* were recorded using photography and scaled drawings, and their features compiled in an electronic database. The preserved hull of *Edwin Fox* was scanned by laser, which produced an accurate three-dimensional (3D) digital model. The 3D digital model was used to measure the hull and to produce a lines plan of the vessel. Detailed recording of the ship's hull and timbers revealed the way in which shipwrights shaped and used timber resources in vessel construction.

Furthermore, the author conducted additional site visits to the Edwin Fox Maritime Museum in April and September 2017 for timber sampling, and in January 2018. This fieldwork included the recording of structural components, such as framing, planking, fasteners and fittings, revealing how the ship was constructed. The fieldwork team of volunteers inspected the timbers for tool, assembly and construction marks, which all provided evidence for understanding how shipwrights interacted with materials during the ship's construction.

A timber catalogue was created for *Edwin Fox* following Richard Steffy's (1994:207) guidelines that employ sub-catalogues within the following main categories:

- keel, keelson, stem and sternpost;
- frames;
- planking (outer, ceiling, deck timbers);
- ceiling; and
- unclassified members.

This catalogue retains observation notes, measurements and other information collected on the targeted timbers amidships. It also provides museums with a current database of information collected during the fieldwork.

This study required the collection of timber samples from *Endeavour*, HMS *Buffalo* and *Edwin Fox* for wood species identification. The author, assisted by Rod Wallace, Department of Anthropology, University of Auckland Te Whare Wānanga o Tāmaki Makaurau, identified the wood species of specific ship timbers with a visual inspection of the wood cell structure under a microscope. Several published reference collections were used, including the InsideWood database (Wheeler et al. 2007), *Photomicrographs of World Woods* (Miles 1978), *Identification of the Timbers of Southeast Asia and the Western Pacific* (Ogata et al. 2008) and the *CSIRO Atlas of Hardwoods* (Ilic 1991). Timber samples came from comparable structural components of the ship's hull, including outer planking, inner planking, frames, futtocks and wales.

The dendrochronological investigation of *Edwin Fox* revealed relative timber ages and conversion and tested whether timbers were milled in pairs from the same parent tree. The visual inspection of the dendrochronology core samples was completed by the author under the supervision of Gretel Boswijk at the Tree-Ring Lab, University of Auckland Te Whare Wānanga o Tāmaki Makaurau. *Edwin Fox* was the only case study investigated using dendrochronological methods because it was the most complete of the three ships and offered timbers with contextual information. The condition of the other two vessels' museum timber collections was unknown prior to recording and therefore were not considered for dendrochronology at the project planning stage. The results from this study, however, present a future opportunity for applying dendrochronology to several *Endeavour* timbers.

Copper sheathing was examined for evidence of patent stamps or government marks and underwent semi-quantitative analysis for metal composition identification using an EDAX detector in a Scanning Electron Microscope. John Bingeman et al.'s (2000:227) paper illustrated a range of patent stamps and government marks evident on nineteenth-century British naval vessels. This catalogue aided the identification of marks observed on HMS *Buffalo* and *Edwin Fox*. Furthermore, Mark Staniforth (1985:29–31) discussed the methods of positioning the copper sheets to ships' hulls. The methods include overlapping, direction of overlapping and different fasteners. Interpretation of metal sheathing used on the three primary case studies show differences in antifouling technologies.

Identifying differences in construction technologies across the three case studies assists in determining for the first time how the ship's hull of British East Indiaman has changed over time and second, how the adaptation to local timber resources contributed to the development of ship design. Furthermore, historical research identified the social, political and economic influence on ship construction and determines the cause for foreign shipyards and the use of unfamiliar timbers in new regions. This historical research places into context the need for shipyards in new colonies and how the underlying conditions at the time of construction influenced shipwrights to adapt to new environments.

As a result of this research, a framework is presented to illustrate technological innovation of ship design over time. This study adopts Michael Schiffer's (2004:581) performance characteristic matrix to illustrate changes in antifouling technology seen in the three case studies. Furthermore, an S-curve model is constructed to illustrate ship development over time, specific to the three case studies. The S-curve demonstrates how the adaptations lead to innovation during BEIC ship construction between the eighteenth and nineteenth centuries.

1.7 Permissions, ethics and consultations

This research involved collaboration with five different museums and the Tree-ring Laboratory at University of Auckland. The museums include the Edwin Fox Maritime Museum, Southland Museum and Art Gallery Niho o te Taniwha, the Mercury Bay Museum, the National Museum of the Royal New Zealand Navy and the New Zealand Maritime Museum Hui te Ananui A Tangaroa. Permissions to access museum materials and laboratory resources were granted for this study. Access to the *Endeavour* timber collection at the Southland Museum and Art Gallery Niho o te Taniwha was granted by David Dudfield, Curator of History and by Neville Ritchie, formerly technical advisor: Historic/Archaeologist, at the Department of Conservation Te Papa Atawhai. Additionally, access to the Mercury Bay Museum's HMS *Buffalo* timber collection was granted by Rebecca Cox, the museum's manager. The researcher and the Marlborough Heritage Trust which administers the Edwin Fox Maritime Museum signed a memorandum of understanding to access the *Edwin Fox* hull for this research. Gretel Boswijk, Tree-ring Laboratory director, presented a formal letter of invitation on 10 August 2017 which permitted the researcher to analyse the timber samples at the University of Auckland.

1.8 Chapter outline

1.8.1 Chapter 2 Literature review

Chapter two explores nautical archaeological studies using a behavioural framework and argues against using evolutionary ship models when discussing changes in the art of shipbuilding. This includes reviewing behaviour modelling, highlighting technology transfer and innovation, and exploring processes relating to ship construction. Finally, the chapter reviews previous literature on archaeological ship recording and vessel reconstruction studies.

1.8.2 Chapter 3 Contextualising the past

Chapter three describes the historical context relating to British shipbuilding during the eighteenth and nineteenth centuries. Specifically, it defines key terms used in this thesis, it synthesises the British East India Company's operational history, it describes the ships used in the global trade routes between Britain and the East Indies and outlines the changing adaptability as a result of foreign shipbuilding timber resources. Previous East India Company archaeological investigations are also examined here. Finally, this chapter highlights past research pertaining to *Endeavour*, HMS *Buffalo* and *Edwin Fox* and reviews literature about them in order to understand site formation processes over time.

1.8.3 Chapter 4 Methodological approaches

Chapter four outlines the methods used to collect information and data for this research. The archival and archaeological research is described in this chapter, alongside wood identification, metal composition analysis, fibre identification, organic analysis and dendrochronology.

1.8.4 Chapters 5–7 *Endeavour*, HMS *Buffalo* and *Edwin Fox* results

These three chapters present individual results for the three case studies. Hull design parameters and shape are presented. Then, dimensions, form and function of timbers from *Endeavour*, HMS *Buffalo* and *Edwin Fox* are described in context of examining the materials through a technological lens to reveal transfer of knowledge, adaptations and innovations over time. Material analyses and identification are also presented in these chapters.

1.8.5 Chapter 8 Discussion

Chapter eight discusses the differences and similarities found between the three primary case studies using the archival research, archaeological data, material analyses and the dendrochronological results. Then the primary case studies are examined alongside other previously investigated East India Company ships to increase the data set when exploring development over time. Technological innovation is assessed using a matrix framework and an S-curve model to express the development of these watercraft over time is presented here. Finally, new insights into shipwright behaviours are revealed.

1.8.6 Chapter 9 Conclusion

Chapter nine concludes this thesis by answering the research questions and addressing the aims of the project. Limitations encountered during the project are highlighted here. Future research directions are presented to enhance our knowledge of British colonial shipbuilding and contribute to the ongoing development of the discipline of nautical archaeology.

1.9 Conclusion

This research examines structural features and construction technologies associated with BEIC ships during the eighteenth and nineteenth centuries. In addition, using behavioural and technology transfer frameworks, this study establishes how British shipwrights adapted to different environments and how this influenced BEIC ship design. The *Endeavour* and HMS *Buffalo* ship timbers and the surviving *Edwin Fox* hull provide three cases studies with preserved tangible evidence that reflect British shipwright behaviours and British merchant ship development. This thesis contributes to nautical archaeological studies relating to ship development and enriches our understanding about British shipwrights’ practices and knowledge.

Chapter 2. Literature review

2.1 Introduction

Past ship studies have often used evolutionary models to explain the development of watercraft over time (Greenhill 1988; Pomey et al. 2012; Zwick 2013). Such models repeatedly imply that ship typologies are thus developed in an upward progression of improvement. What this chapter highlights, however, is that ship development is not necessarily linear, and that similar innovations can develop independently across two geographic regions. The implications of this are twofold. First, no longer should nautical archaeological research focus on explaining linear typologies, rather ship studies should explore vessels individually to provide explanations on new developments. Second, by exploring ships individually and then combining them into larger data sets, we can extract trends that impacted the shipbuilding industry and ask what influenced changes in design and construction technologies. This thesis applies a behavioural framework approach to explore the changes in British East Indiamen ship design and construction technologies during the eighteenth and nineteenth centuries.

2.2 Social learning

Henry Glassie (1975:66) suggested social theory is formed in relation to real phenomena. It must explain the trends, but only in its combination with theory will it enhance our understanding of the humans who caused the phenomena to exist. In the case of shipbuilding, the shipwrights themselves learned their trade as apprentices with individual development a result of social learning practices. Thus, when investigating patterns of ship construction over time the researcher must become familiar with theories of histories and models of change combined with social and human facts (Glassie 1975:66).

Social learning is a powerful adaptive process that allows one to learn from those who have failed first (Henrich 2001; O'Brien and Bentley 2011:315). Humans are great social learners whereby they learn new things from others, improve on those things and transmit them to the next generation. For example, humans learn languages, morals, foods for consumption, technology and ideas from other people (O'Brien and Bentley 2011:315). The effect of this social learning results in a continued form of knowledge between people and things over space and time.

Michael O’Brien and R. Alexander Bentley (2011:317) argued that variation within individual learning is considered a slow process controlled by the individual who modifies existing behaviours through trial and error to suit their own needs. Robert Boyd and Peter Richerson (1985) referred to this as ‘guided variation’, having two important and equal components—unbiased transmission and environmental (individual) learning. On one hand, a learner can copy a behaviour from a parent or master and not have any influence on the behaviour before passing it on to the next person. On the other hand, the environmental learning model is an individual learning process which can occur many times during the same generation and through multiple generations (Henrich 2001). It is possible that guided variation of the learning process existed within shipwright apprenticeships. In theory, a shipyard could experience both unbiased transmission and environmental learning of shipwright knowledge and therefore, influence the formation of the ship itself.

Social learning is not a single path of progression, rather variations are caused by the learner and/or their surroundings. When assessing social learning variation, there are competing thoughts. Joseph Henrich (2010) argued that in theory the more minds there are, the more variants (Fitzhugh 2001; O'Brien and Bentley 2011:325). Whereas Alex Mesoudi (2011) highlighted that individual learning in no way needs variation in the population to work, nor does the learning rely on the frequency of variation. It is, therefore, possible for social learning to exist both in isolated individuals and communities as well as with connected people and groups. Thus, social learning only sorts the relative frequency of variants across a population, rather than creating those variants (O'Brien and Bentley 2011:325).

In the context of shipbuilding, generations of shipwrights continue to replicate behaviours through either copying while also slowly improving something, or by choosing to copy based on their social surroundings, such as friends, family and master shipwrights. People let others filter their behaviours, enabling those who will receive the new information to benefit from improved knowledge (O'Brien and Bentley 2011:315; Rendell et al. 2011a). Furthermore, the act of copying permits the person to adjust to their surrounding environments. Thus, acquiring in-depth knowledge from others, populations have the ability to respond to changes that impact them as individuals and as communities (O'Brien and Bentley 2011:316). It is argued here that the constant replication of shipwright behaviours reflects changes in the surrounding environments.

2.3 Cultural transmission

Together, cultural transmission theory and technological differentiation explains patterns in material remains that are influenced by different circumstances (Eerkens and Lipo 2007:247). Franz Boas (1937:295) argued:

> We see everywhere types of culture which develop historically under the impact of multifarious influences that come from neighbouring people or those living far away.

Studying artefacts and their attributes allows researchers to track the transmission of information about manufacture and modification (Eerkens and Lipo 2007:261). As identified by Jelmer W. Eerkens and Carl P. Lipo (2007:261), the difficulty is controlling the social and physical context of the information transfer. The study of historical ships, however, provides researchers with additional archival records to answer these and other contextual questions, including those relating to political and economic considerations (Eerkens and Lipo 2007:261; Green 2008:1600–1601). Furthermore, it enables archaeologists to explain aspects beyond typology and answer questions about *why* and *how* artefacts change over time (Eerkens and Lipo 2007:240).

Cultural transmission is the process of information transfer between individuals or groups. To understand this transfer, Eerkens and Lipo (2007:246) suggest this process should be broken into large ‘social units’ that survive transmission. They describe these social units as ‘invention or modification’, ‘winnowing and selection’ and ‘cultural variants’ that influence change over time and the transmission of knowledge (Figure 5) (Eerkens and Lipo 2007:246). By breaking down the transmission of information into social units, researchers can understand the processes of learning and consider how this affects the transfer of knowledge. Therefore, understanding these processes means that factors that were driving human decisions and influencing change on material culture can be identified.

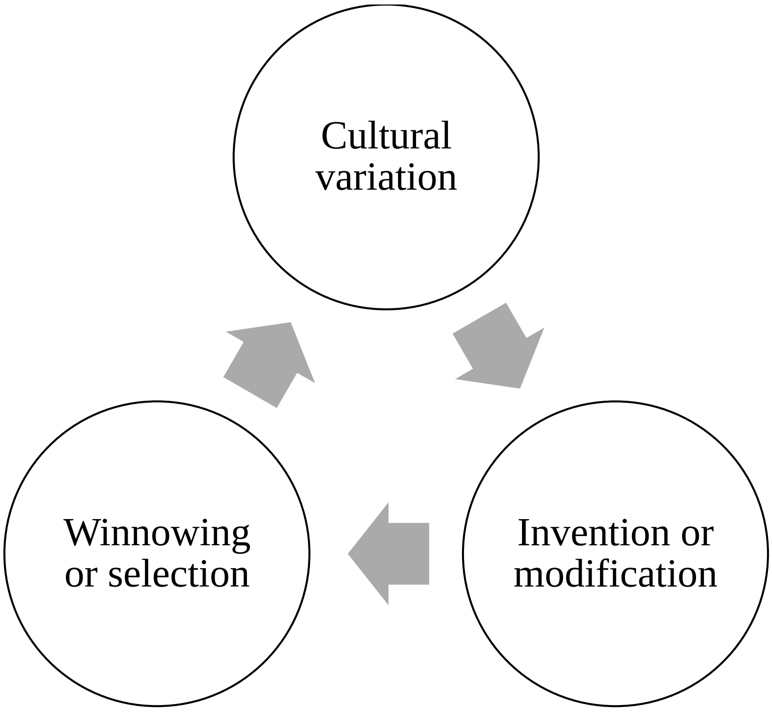


Figure 5. Transmission processes affecting evolution (after Eerkens and Lipo 2007:246).

Understanding these human decisions is important because it supports the conceptual approach that objects do not evolve by themselves; instead they are the end result of human behaviours. Thijs Maarleveld (1995:3–4) highlights this by saying:

> ‘Evolution’ is a neutral term meaning movement or change, it implies thinking about ship development as being autonomous rather than being a function of human decisions regarding continuity and adaptations.

Therefore, to understand these human decisions and to avoid the misconception that shipbuilding is autonomous or evolutionary, archaeological ship research must incorporate a combination of methodologies and behavioural frameworks to understand and measure human decisions influencing ship development (Adams 2013; Zwick 2013). This understanding of change in shipbuilding cultures presents the question, did newly established shipbuilding industries in the colonies develop their own cultures and if so, how were they different to the culture of origin?

Cultural transmission is originally formed on the basis that genes and culture are linked through systems of inheritance, variation and evolutionary change (O'Brien and Bentley 2011:311). Cultural transmission produces similar traits of behaviour that cannot be identified through genetic transmission on the continuity of the environment (O'Brien and Bentley 2011:311; Shennan 2011). In addition to Michael Schiffer's (2005:486) Complex Technological Systems (CTS), cultural transmission is applied to explain how information makes its way across the social landscape (Henrich and Boyd 1998; Mesoudi 2011; O'Brien and Bentley 2011:311; Rendell et al. 2011b).

O'Brien and Bentley (2011:311) demonstrate how key components of cultural transmission—invention and innovation—are central to the development of CTS. They acknowledge that key terms can be used interchangeably in social-learning literature. They define invention as a novelty and innovation that has diffused through a population; however, 'if a novelty does not diffuse, then it does not qualify as an innovation' (O'Brien and Bentley 2011:311). Thus, invention can occur at any time whereas innovation is the process for which knowledge and skill have transferred through a population.

Cultural transmission theory proposes that similarities between behaviour and artefacts may be influenced by the exchange of information using a nongenetic mechanism (Eerkens and Lipo 2007:240). Archaeological studies that have applied this theory have revolved around understanding variation within and between assemblages of artefacts and their traits (Eerkens and Lipo 2007:260). Benjamin W. Roberts and Marc Vander Linden (2011:12) argued that investigations that explore production, use, distribution and deposition in relation to social behaviour, have the ability to establish datasets which can reshape our understanding of the broader archaeological record. Therefore, the patterns derived from structural and design attributes of a ship can inform the archaeologist about past shipwright behaviours and learning processes that they might have experienced.

Humans, through individual learning transmission, can continually acquire, modify and pass on information through the processes of individual experimentation (innovation) and social learning (copying) (Eerkens and Lipo 2007:242).

Consequently, these processes allow individuals to respond to environmental changes more effectively (Eerkens and Lipo 2007:243). Thus, the study of shipwright behaviours is well placed to investigate this response behaviour and to understand how they were adapting to their surrounding environment, both culturally and environmentally. Hence, understanding external factors, such as social, political, economic and environmental considerations provides evidence about shipwright individual learning behaviours and how they influenced ship development.

2.4 Behavioural archaeology

Behavioural archaeology provides a framework for the study of technological change (Schiffer 2004:579). Through an American scholarly lens, the study of technological change gained an interest from academics in the decades leading up to the year 2000 (Schiffer et al. 2001:730). It revolved around a set of generalised concepts and principles useful for technological studies for understanding change and development (Schiffer et al. 2001:731). William Rathje and Michael Schiffer (1982:64–67) examined the dimensions of artefact variability—formal, spatial, quantitative and relational. The functions from these artefacts were then categorised using terms, such as techno-function, socio-function and ideo-function (Rathje and Schiffer 1982:67, 78, 91–93; Schiffer et al. 2001:731). Schiffer (2004:579) highlighted that every activity consists of interactions among people and technologies. He argued that technology interactions are not meticulously researchable until formulated in behavioural terms (Schiffer 2004:579; Schiffer et al. 2001:731). Due to the complexities of ships and their use of technology, researchers must consider and apply a range of behavioural theories and models (Schiffer 1988; Schiffer 1993, 2000; Schiffer et al. 2001:731).

Schiffer et al. (2001:731) explained that the life-history framework has become a popular tool for students studying technology and developing flow models and behavioural chains. The model includes all aspects of an artefact, such as the entire manufacturing process and continues beyond its operational history (Schiffer et al. 2001:731). Specifically, a technology’s life is reflected through a simplified sequence of activities that range from the time of procurement, use, reuse, deposition, to archaeological recovery and analysis (Schiffer 2004:580). Since the life-history of a technology can be expressed as a sequence of activities, it now becomes a flow model illustrating the development of technology overtime (Schiffer 2004:580). Thus, flow models are invaluable to the study of technological change pertaining to ships with questions developed in relation to the processes of invention, design, replication and adoption (Schiffer 2004:580).

Schiffer et al. (2001:731) argued that ‘behavioural studies have also clarified, in general terms, the complex relationships among a technology’s technical choices, material properties and performance characteristics.’ Performance characteristics underlie all interactions in activities and are essential to behavioural studies of technology (Schiffer et al. 2001:731). The concept of performance characteristics is important to behavioural studies and over time has been applied as an interaction and activity, specific to a person or artefact (Schiffer et al. 2001:731). Therefore, it is important to examine choices, properties and characteristics within a ships’ structure to understand the behaviours employed in their selection.

Social influences affecting performance characteristics such as age, sex, ethnicity and social class also need to be included in the behavioural model to allow for more specific discussions regarding the human element in using a technology (Schiffer et al. 2001:732). This allows the researcher to understand not only the technology acting as a material but also social decisions involved in using a technology. Therefore, behavioural principles and techniques can enhance our ability to extract function and use activities from artefacts and other materials. Identifying these activities lays the foundation for studying technology in archaeological cases such as ships (Schiffer et al. 2001:731).

The study of ship construction is well placed for analyses using a behavioural framework, and to incorporate performance characteristics, because watercraft creation incorporated a variety of technologies. In addition, ship technologies were created, modified and refined by people who in turn applied shipbuilding knowledge learned across generations. Specifically, using such a framework directs researchers to explore a variety of factors that influenced ship artisans’ technical choices towards certain technologies (Schiffer et al. 2001:732). Thus, we can examine how shipwright behaviours influenced ship design and construction.

2.5 Behaviour modelling

Evolutionary theory is used in archaeological studies but has often been criticised for its application (Schiffer 2008b:104; Zwick 2013). The use of evolution implies a linear progression and when applied to ship studies it constrains theoretical thought to a narrow path. In our subconsciousness, we 'evolutionise' ship typologies as a single form of progression and of continued improvement. What evolutionary theory fails to support, however, is that technological development can happen at the same time in two different places with no direct contact between individuals or groups. When applied to the study of *Endeavour*, HMS *Buffalo* and *Edwin Fox,* it is impossible for the vessels to follow the same singular line of development.

In an American context, and using ceramic studies as an example, there is a strong argument that 'change' in the material culture is not linked to the use of the term evolution (Schiffer et al. 2001:729). Researchers are careful not to use 'value-laden' terms such as progress nor do they refer to Darwinian theory (Schiffer et al. 2001:729). Rather, researchers are applying diverse social and behavioural theories to contextualise sequences of technological change (Schiffer et al. 2001:730). Thus, comparing behavioural capabilities to explain technological change is best suited for the investigation of the three case studies selected for this research.

Michael Schiffer (2008b:104) highlighted that the application of evolutionary approaches refocuses our attention away from asking more significant questions. He continued by suggesting that researchers ask questions relating to behavioural models involving invention, replication and adoption to understand technological change (Schiffer 2008b:104). The study of the inventive process has been historically applied in social sciences (Arthur 2009; Basalla 1988) but not so much in archaeology (O'Brien and Bentley 2011:311). Continued debate suggests the study of technologies are context dependent and formed by historically constituted conditions (Schiffer 2005:485). By expanding our investigative approach to include these processes, we can use behavioural models to examine specific archaeological and historical contexts, to understand causes for change (Schiffer 2008b:104). Thus, a technological behavioural approach is acceptable for examining the individual development of watercraft over time.

Schiffer’s (2005:486) cascade model, developed from Thomas P. Hughes’s (1983) model, ‘reverse salients’, is a ‘behavioural adaptation, elaboration and generalisation’. A cascade model is used to explain ship performance problems whereby adopted inventions solve one problem, only for unforeseen problems to occur, which encourages new invention wave processes (Schiffer 2005:486). As variants of a technology, inventions and their performance differ, which affects their adoption and subsequently their performance problems (O'Brien and Bentley 2011:314). Therefore, the cascade model aids archaeological research to pursue, recognise and explain certain patterns of variability that might otherwise go unnoticed (Schiffer 2005:487).

The combination of both individual and social learning provides a linking mechanism between Schiffer’s cascade models and the encompassing CTS (O'Brien and Bentley 2011:324). Within a cascade model, inventions deemed unsuitable are not replicated, some that have potential may be adopted, those considered successful are replicated and adopted widely, and others that have no suitable variants are terminated (O'Brien and Bentley 2011:314). Schiffer (2008b:110) uses the overarching cascade model to explain CTS and defined it:

> …as any technology that consists of a set of interacting artefacts; interactions among these artefacts—and people and sometimes environmental phenomena—enable that system to function (Schiffer 2005:486).

This definition offers the archaeologist flexibility for interpreting a specific technology and whether it is determined to be a CTS or not (Schiffer 2005:486). O’Brien and Bentley (2011:312), however, do not agree entirely with Schiffer for several reasons. In particular, they highlight the role in which Schiffer assigns selection in the creation of technological variants (O'Brien and Bentley 2011:312). With constructive criticism in mind, the authors’ critique is more of an opportunity to expand on Schiffer’s insights into how innovations are created and diffused (O'Brien and Bentley 2011:312).

Michael Schiffer considered human life as a mixture of endless and diverse interactions between people and material things regardless of place or time (O'Brien and Bentley 2011:310; Schiffer 2008a:ix). This perspective has led him to study modern material culture and to develop the CTS (O'Brien and Bentley 2011:310). O'Brien and Bentley (2011) argued that Schiffer's development of the cascade model was a turning point in the study of technological change within the discipline of archaeology. Schiffer suggested that improvements can be made when using the model, reminding us that archaeologists have seldom exercised the generalised research option when studying invention (O'Brien and Bentley 2011:311; Schiffer 2005:499).

To explain a CTS, a life-history consisting of a minimal set of processes needs to be established (Figure 6) (Schiffer 2005:488). At a minimum, Schiffer (2005:488 and 499) prescribed life-history of processes as the creation of a prototype, replication or manufacture, use and maintenance. He also noted, that these processes do not form a linear structure as some processes may occur in parallel and/or repeat (Schiffer 2005:488). This is important to understand as it provides a level of flexibility for the archaeologist to explore non-bias and specifically non-typological artefacts. It ensures the research design has manoeuvrability that goes beyond a linear evolutionary path.

Establishing life-history processes helps to guide research in identifying behaviourally relevant ship technology performance characteristics and also contributes to the organisation of the performance matrix (Schiffer 2004:581). For example, Schiffer's (2004:581) study of lighthouses, divided the life-history of competing technologies into three groups of processes: (1) acquisition and installation; (2) functions; and (3) operation, maintenance and repair. It is expected that different social groups participating in different activities in a technology's life-history will have different performance characteristics (Schiffer 2004:581). Specific to this study of BEIC ships, the marine board (social group A) might favour a particular technological design whereas the shipwright (social group B) from their own knowledge might favour an entirely different design which performs the same function.

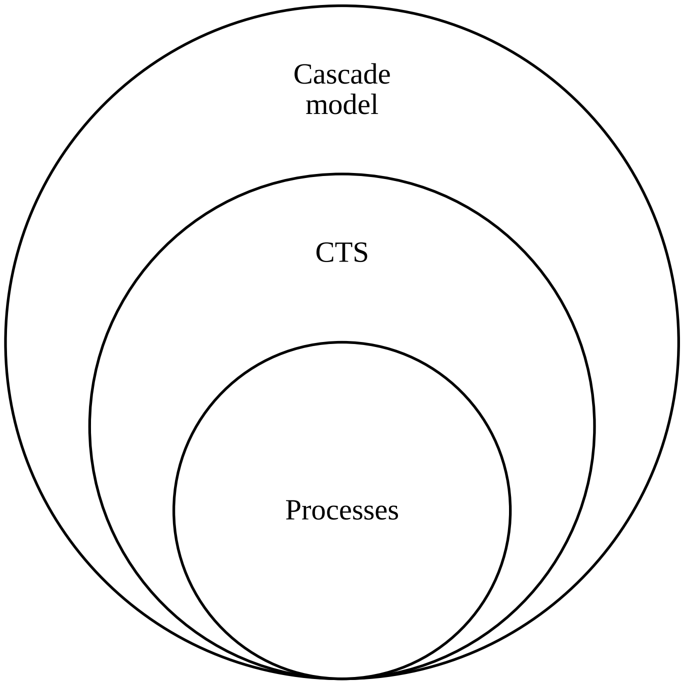


Figure 6. Cascade model encompassing CTS and life-history processes.

CTS development and cascades can occur on any technological object and it is possible to find a hierarchical cascade of invention (Schiffer 2005:489). Once the artefacts are identified as likely to be part of a CTS, they then need to be sorted into life-processes and by time and space distributions (Schiffer 2005:496). From here, trends within the archaeological record can be extracted and identify points in time where invention spurts may start. An example of this is the development of the automobile in the 1890s, with a cascade of prototypes featuring different propulsion powers (gas, steam, electricity, gasoline, compressed air and springs). Manufacturers favoured gas, steam and electricity and, as a result, inventors created new designs for parts, assemblies and for each type of vehicle (Schiffer 2005:489). Then in the following decades, gasoline and electric cars prevailed and spurred another series of invention cascades, developing vehicle body styles and interior fixtures and fittings (Schiffer 2005:489). Reviewing a cascade model provides insight into the bursts of inventive activities that take place during the development process (Schiffer 2008b:110). This demonstrates the process by which a technology is started and with continued development is stimulated by various levels of adoption and invention. In reference to ship technologies, the examination of antifouling during the eighteenth and nineteenth centuries on British East Indiamen is one example of a technological cascade (see Chapter 8).

One outcome from employing Schiffer's cascade model in this study is the ability to identify performance problems during the life-history processes in the CTS. Schiffer uses the thought-provoking example of the development of the bow and arrow to demonstrate that 'ancient hunters' did not arrive at the finished product after the first try but through trial and error (O'Brien and Bentley 2011:310; Schiffer 2005:495). When applying the same thought to nautical studies, one immediately jumps to the sinking of the ships *Mary Rose* in 1545 and *Vasa* in 1628 (Hocker 2006; Marsden 2003:130–134). These vessels famously sank due to carrying armaments too large for their size, among other factors. They were underbuilt—and in the case of *Mary Rose,* rebuilt—with a trial and error approach to ship's architecture and performance when afloat. The building of these ships, considered to be the pride of their respective nation's navies, illustrate the development, adoption and inventive approach to the construction of sailing vessels in a complex technological system of naval shipbuilding. On the other hand, Zwick (2013:47) points out that more general advantageous qualities of hull design can occur more by coincidence (trial and error) than intentionally. He then questions whether the greatest impetus for innovation and change *evolved* locally through trial and error (Zwick 2013:51).

To measure variation influencing technological development, Schiffer (2010:128) argued that a process of long-term or large-scale behavioural change recognised in the archaeological record is technological differentiation. To understand this process of change, Schiffer (2010:129–133) expressed technological differentiation as a framework through a six phase process; 1) Information transfer; 2) Experimentation; 3) Redesign; 4) Replication; 5) Acquisition; and 6) Use. He then explained further that the researcher must specify the technology of interest, identify the variants and functions, identify user groups and activities associated with the variants and consider the impact of the redesigned variants in terms of performance and situational factors (Schiffer 2010:134). This process is important for constructing explanations about the design of new variants. Therefore, this framework can be applied to the study of ship development by researching the variants involved in the process of ship construction. Furthermore, Schiffer's (2010) framework can be used to explain the sharing of information between individuals, such as shipwrights and naval designers, which contributes to understanding the processes of cultural transmission that influenced ship design and construction.

Schiffer (2008b:110) argued that the study of transmission processes using archaeological materials is misplaced because artefact lineages are a product of replication and adoption processes, not exclusively transmission. Once something is invented, replication of technologies is formulated on the process of manufacture and exchange (Schiffer et al. 2001:732). Questions tend to focus more generally on the organisation of production and exchange (Schiffer et al. 2001:732).

Specific to the study of watercraft, Pomey et al. (2012:305) argued ships are a long and complex evolutionary phenomenon and transition over time comprises several roots. To demonstrate this, the general design of the transmission chain method suggests largely a linear form of progression with parallel paths of progression (Figure 7) (Mesoudi 2008:92). This, when applied to a study of ships, indicates a general and uniformed line of development over time. This model might be appropriate for examining watercraft more generally over millennia; however, it is argued here that it is inappropriate when investigating vessels that employ a range of technologies and human behaviours over a short period of time. The model lacks allowance for an increased frequency of variations encountered along the path of development, as well as the transfer of knowledge through individual and community social learning. This form of chain model is therefore excluded from this study.

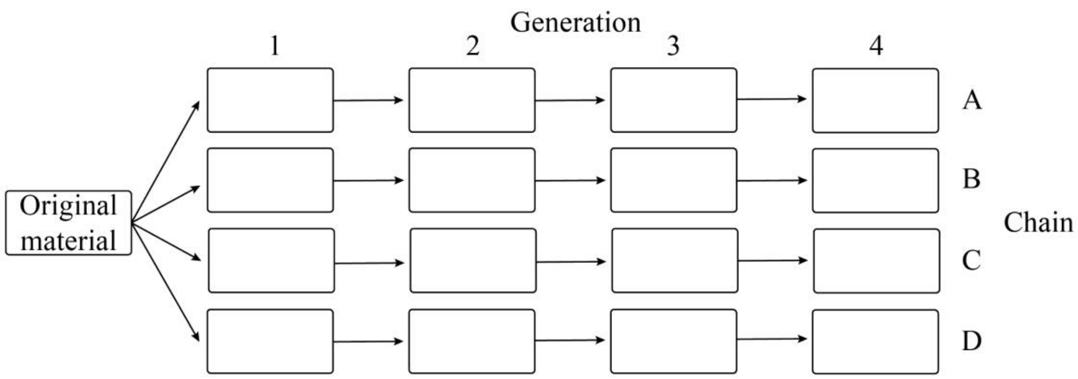


Figure 7. Chain model (after Mesoudi 2008:92).

Schiffer (2005:496) stated that behaviour models are capable of establishing 'a foundation for constructing historical narratives of technological change.' He continued by acknowledging that the construction of the historical narrative leaves room for archaeologists who choose agency, constructionist or evolutionary explanations to construct their own narratives on behaviours (Schiffer 2005:496). A CTS can include technological objects made by skilled workers working with many different materials (technologies) (Schiffer 2005:496–497). Ships are complex objects made up of many different components, manufactured from various resources and sculpted by several generations of knowledge. A CTS is only one of the ways, however, to understand the variety of inventive processes in human societies (Schiffer 2005:499). Schiffer (2005:499) believed that the door is still open for devising new models and theories that can complement narratives relevant to invention processes in specific behavioural contexts, such as the application of CTS. By constructing generalised models of invention processes, archaeologists can make significant contributions to the study of technological change (Schiffer 2005:499). Therefore, the application of the CTS to ship construction studies is appropriate and incorporated into this research. Furthermore, using the results extracted from the case studies, a new development model specific to ships is proposed. Thus, stepping through Schiffer's door and devising a new model assists in explaining the development of watercraft over time.

2.6 Technology transfer

O'Brien and Bentley (2011:314) agree with Schiffer's (2008b:110) description of CTS and cascades of invention and maintain they are '…quite compatible with studies of cultural transmission.' Drawing from studies relating to cumulative cultural evolution, knowledge that has been passed down from generation to generation throughout history, provokes the question as to what has driven the burst of technological complexity (O'Brien and Bentley 2011:314; Tennie et al. 2009)?

Over generations, technological knowledge that becomes irrelevant will be dismissed, even if the technology is adaptive (O'Brien and Bentley 2011:314). Knowledge and specialist skills become lost or are difficult to transfer, especially when seen in population decrease (Henrich 2004; O'Brien and Bentley 2011:314–

315). This can also be applied to the examination of shipwrights who built BEIC ships. As technologies are invented, changed and adopted, those which are deemed irrelevant are then excluded from the CTS present within the shipbuilding industry. In particular, the trade of shipwrights was taught through apprenticeships, a form of social learning, which is defined as learning by observing or interacting with others as opposed to learning independently (O'Brien and Bentley 2011:315). Not all learning is social, however, as social learning spreads behaviours but relies on individual learning to generate them (O'Brien and Bentley 2011:315). This is why O'Brien and Bentley (2011:315) argue, it is important to distinguish between invention and innovation.

Daniel Headrick's book (1988:19) *The Tentacles of Progress: Technology Transfer in the Age of Imperialism 1850–1940*, argued that it is wrong to think that sudden 'invention' followed by diffusion reflects technological change. Rather, both processes operate simultaneously. Headrick (1988:9) described the transfer process as not one but two processes. The first, relocation, from one geographic region to another, involving methods, equipment and the knowledge to operate them. The second is diffusion of knowledge, skills and attitudes from one society to another. Ships at one point in time were an invention but throughout time, innovation occurred through adaptation, improvement, enhancement whilst diffusing among populations. This is because innovation is driven by external factors such as technologies, environments and economies. Therefore, this research examines, geographic boundaries, available materials, technologies and economy to understand the diffusion of colonial merchant shipbuilding within British and Indian societies.

2.7 Structural innovation

The building of ships requires many individual components to fit, complement and work with each other to support the overall integrity of the structure. The development of these components arrives from the invention and adoption of various technologies formulated through human behaviour. In the context of built structures, Glassie (1975:66) highlighted, using his study of houses to investigate the history of structures, the researcher, '…must begin with the houses themselves, at nail heads and window sizes and room arrangements.' When applied to ships, analysis must investigate and record the minute details (material composition and fasteners) to the overall size and shape of the vessel (the complete structure). This, combined with behavioural models, allows us to explore new thinking relating to the process of BEIC shipbuilding in the eighteenth and nineteenth centuries.

Glassie (1975:66–67) has argued that there is much more to add to previous historic studies in relation to human behaviour. He offers self-reflection suggesting that we have much information about people but little understanding about their actions (Glassie 1975:66–67). Through combining different data collection methods, we can gain a fuller recognition and understanding of human behaviours (Bennett and Fowler 2017:28). This study incorporates several methodologies, including historical research, archaeological data, dendrochronology and material analysis to assess human behaviours towards shipbuilding. In order to observe shipwright behaviours, we must understand change using behavioural theories of innovation (Glassie 1975:67). Therefore, structures cannot teach us much about the history unless we apply them to models of change that clarify our understanding about people of the past (Glassie 1975:67).

Glassie (1975:67) described variation in reference to the ‘maker of houses’ as a journey through architectural experience. The experiences of an artisan are formed by the metaphoric journey of bouncing between walls (ideas) in a forward progression and although knowledge is randomly acquired, it is systematically ordered. So by the time the artisan comes to construct something his or her ideas are no longer those of a copyist but of a knowledgeable master (Glassie 1975:67). The person’s final designs are then a construction of taking the best out of several original learnings while reflecting variation. The final products result in being similar to each other but never identical (Glassie 1975:67). This is also a result of the guiding of information between designer and builder. For example, an architect may specify that a door is placed symmetrically within in the structure, however, the builder’s performance may result in the door not being perfectly placed as instructed (Glassie 1975:68). When considering the construction of BEIC ships, limited designs and ship models were all that were available. After the company provided the overall dimensions of the vessel, it was up to the shipwrights to construct it and construct it using the methods they knew best. Therefore, it is very probable that not all the ships were constructed the same, nor was the specified design transformed into an exactly replicated tangible object.

The same philosophy can be applied to ship scale model building in the sense that the models created 'directly' from the original vessel may not be an exact carbon copy or vice versa. It was common for the shipwright's name to be on the model, but it is unclear if the shipwright was the model maker as well as the designer of the ship (Peters 2013:192). The model maker would be directed by their own requirements and skill level to make the individual components fit. Charles Dagget and Christopher Shaffer (1990:145) have argued that while there are working models of men-of-war, there are no comparative models of eighteenth-century BEIC ships. The most complete example is that of *Somerset* (1738), however, the model would need to be dismantled to compare and assess the accuracy of the inner workings to that of a real BEIC vessel (Daggett and Shaffer 1990:145). Therefore, this study excludes an analysis of models, although they are used for illustrating generalised stylistic traits and hull forms. In addition, the recording of archaeological remains provides a unique opportunity to investigate construction methods employed in the building of Company ships.

2.8 Exploring process

As argued by Richard Gould (2000), conceptual approaches to the study of ship construction are significant for documenting human behaviour. Within these behavioural theories and change models are processes (invention, replication, adoption), which need to be explored to identify behavioural factors of influence (Schiffer 2004:580; Schiffer et al. 2001). More generally, Joe Flatman (2003:147) argued that material culture must be examined through its whole existence, process, production, exchange and consumption. Through the lens of technological change, Schiffer (2004:580) stated that *some* archaeologists borrow theories and models from other disciplines. He continued stressing that archaeologists have the ability to construct their own principles and tools because they have access to archaeological and historical records which allows for their studies to examine change over decades, centuries and millennia (Schiffer 2004:580). The eighteenth and nineteenth centuries are well placed for studying ships with accessible archaeological sites and a plethora of historical resources. Thus, nautical archaeologists have the flexibility to explore and adopt behavioural models to investigate shipwright behaviours during this period.

2.8.1 Invention

Invention permits the inquiry relating to the creation of new technologies and varieties of old technologies (Schiffer et al. 2001:732). To Schiffer, invention is everything but a random process; instead, it is patterned by stimulated variation (O'Brien and Bentley 2011:312). Invention process models favour random variability usually influenced by the size of a population (Schiffer 2008b:109). Thus, the resultant inventions, demonstrate technological performance characteristics that are suitable to the culture and its context (Schiffer 2008b:110).

Using ship studies, the process of invention is still argued to follow an evolutionary path. Daniel Zwick (2013:65) explains that evolution does have its place in ship studies whereby it can be approached by understanding mechanisms behind the development of tradition. Considering the term evolution here, some inventions can be functional, whereby they affect performance, whereas others are not (O'Brien and Bentley 2011:312). After discussing invention, Henrich (2010:111) concluded:

> Invention and innovation are fundamentally evolutionary processes. Given that nearly all inventions build on existing ideas and often involve the recombination of existing concepts, methods, or materials often fortified or integrated with a dose of lucky mistakes or happenstance, the overall inventiveness of a social group or population depends on the number of individual minds available to create recombinations, generate insights and get lucky, as well as on their cultural interconnectedness.

This research disagrees with this evolutionary approach and the generalised use of linear progression, but recognises that ideas continue to build upon each other. In a technological sense, the result of interactions between people and environments which produces interacting artefacts, ideas and knowledge (Schiffer 2008b:110). This evolutionary conceptual approach, however, fails to support the possibilities of multiple and similar inventions happening at the same time without any cultural contact between different social groups. By exploring how humans have stored and retrieved information over time, for example, rock art, writing, built environments, material culture and ship construction, it opens the door for researchers to investigate invention processes within different social groups and societies (O'Brien and Bentley 2011:330; Powell et al. 2009; Renfrew and Scarre 1998).

2.8.2 Adoption

Studying adoption is an opportunity for archaeologists to connect variables such as age, gender, ethnicity and social class to explain decision making processes (Schiffer et al. 2001:732–733). Groups that adopt outside influences, base their choices on comparing performance characteristics of competing technologies specific to their chosen activity (Adams 1999; Schiffer 1995:250; Schiffer et al. 2001:733). The use of the performance matrix when used in conjunction with a life-history framework, is a useful tool for comparing competing technologies when studying adoption processes (Schiffer 2004:584). A performance matrix can be used here to assess differences in the behaviourally relevant performance characteristics (Schiffer et al. 2001:733). Schiffer (2004:580), however, acknowledges one critique, being the lack of mature behavioural theories for adoption processes and that the use of the performance matrix as a heuristic tool is one development for investigating technology adoption.

A performance matrix is a table that an investigator can use to compare two or more competing technologies in relation to a set of behavioural performance characteristics (Schiffer 2004:581). Although the matrix itself is a simplistic tool, the table allows for the comparison of both qualitative and quantitative factors and illustrates any major and minor patterns (Schiffer 2004:581, 2008b:105). This allows the archaeologist to handle multiple sets of data that relate to adoption decisions and to pursue patterns that involve past behavioural actions (Schiffer 2004:581).

Schiffer (2008b:104) argued that ‘most technologies and behaviours are adopted by some individuals or groups and not by others.’ He continued by advising that investigators need to identify factors to understand occasions of adoption and non-adoption. As one example, Schiffer (2008b:105) employed a performance matrix to identify trends of the differential adoption of electric arc lighting in lighthouses. Applying a performance matrix, like the one Schiffer uses, to this study enables us to assess ship technology performance characteristics in relation to adoption or non-adoption of ship components. Furthermore, adoption processes are also an important source of variation—consumers become inventors, testing their new products in new actions (O'Brien and Bentley 2011:313). This process results in the increase in activity variation, that links back to understanding processes of invention (O'Brien and Bentley 2011:313).

2.8.3 Design and type

Design is an important component that should be considered for nautical archaeological research. As a continuation from Glassie's (1975:66) investigative approach to historical structures, Steffy (1994:194) notes in reference to watercraft:

> Design is a more subtle subject but is just as important. It includes the documentation of all hull shapes, the arrangement of the structure and just about every other physical property of the hull that cannot be assigned to the construction category.

Steffy (1994:194) argued that there is information that can be gleaned from shapes and the placement of structural components, which can further inform us about the thought processes of the builder when constructing watercraft. Therefore, nautical archaeological research no longer relates to just examining the geometric contour of a ship's hull structure. Ships can be 'read' to create statements of their designers' competence, through examining the arrangement of vessel construction materials (Glassie 1975:114). This insight enhances our understanding about the artistry of the designer and shipwright. Furthermore, it provides insight into the 'type' of vessel constructed for the East India trade.

Michael Schiffer (1976:95–98) evaluated typology as a way to examine classes within a set of types to generate attributes and to determine their relationships. When constructing typologies, recovery percentages should be considered with regards to the categories of artefacts used for analysis. This is because recovery percentages are seen as an error and as a result, some typologies might define unrecovered materials (Schiffer 1976:97). Schiffer (1976:97) concludes his discussion by proposing the question: 'What percentage of the artefacts of this type, originally present in the units excavated, are available for analysis?' Considering this question, previously studied British East India ship archaeological sites are included in this study to minimise error when assessing several ships' hulls. In addition to the three primary case studies, there are several other ships that have undergone archaeological investigations in the past. Combined they provide a greater insight into the design and construction features specific to the merchant ships used in the East India trade.

Maarleveld (1995:6) argued that classifying a ship as a particular type, for example, carrack, galleon, yacht, suggests autonomous development of a type. However as previously argued, technological changes relating to ship development 'are not autonomous at all. They are a result of human decisions.' By studying ships within their broader context and understanding the influences that shaped the construction and design of the vessel, the researcher is able to retrace variability within the British colonial shipbuilding industry (Maarleveld 1995:6).

Traditional approaches in nautical archaeological research have been to create a typology of ships, linking one design to another (Conlin 1998:3). Shipwreck typologies have also been employed to place unidentified shipwrecks into specific cultural and geographical contexts (Loewen 1998). Whereas in the context of this study, it is not precise to include all the ships that sailed to the east and to label them as East Indiamen. This is because the ships, under the same label, transformed in design and construction over time, whether visually or not. For this study, defining the ships in a typology as East Indiamen when referring to the shape of the hulls is used cautiously.

Zwick (2013:61) identified a problem with establishing typologies that a closely fictious typology can align with a real one. Historical type-concepts rarely correlate to an archaeological typology (Zwick 2013:65). He suggests that ship typologies from the late post-medieval period to the modern period can be used with little bias. However, it is easy for archaeologists to accept an historian's typology whereas an archaeologist's typology can be applied differently. Contradictions become prevalent when there is an urge to blend the historical perspective with the archaeological perspective and it is this over-interpretation that creates errors in understandings (Zwick 2013:65). Thus, nautical archaeological studies contribute to confirming the historical record and add new insights into understanding watercraft construction.

Employing an ‘historical type’ in ship studies is problematic and too narrow in focus because it is improbable to reflect a specific construction type. This narrow focus creates a temptation for the researcher to think in a ‘standard type’ which implies a stagnant development before the next type of vessel is introduced (Zwick 2013:49). Ship types (characterised by their historical name), over time, did have their design and construction technologies adapted. Therefore, Zwick (2013:49) instead suggested using the term ‘hybrid types’ to refer to modular variety in a wider set of standard characteristics. Thus, a more general study involving British East Indiamen likely falls within this hybrid type. This thesis, therefore, investigates how British East Indiamen might be classed as hybrids.

When assessing ships as a type, however, the shape of the hull does not always represent a specific group. Seán McGrail (1995:139) summarised the difficulties in classifying shipwrecks:

> If classification schemes are too complex, they run the risk of obscuring patterns; if too simple, the classifier may be tempted to drive them too far and draw unwarranted conclusions.

Ships need to be examined in minute detail because subtle design and construction differences reflect the artistic licence of the shipwright learned through apprentice models. Only then can a more complete understanding of BEIC ships be observed.

Typologies do have their place in ship studies, whereby they serve as a generalised tool for placing an object in a sequence of development. The use of the term ‘East Indiaman’ more generally describes the ships that traded in the ‘East’ (Costley 2014:39). It is known through historical records that *Endeavour* and HMS *Buffalo* were built for the Company. *Edwin Fox*, however, was constructed at a time when the British East India Company was operating solely on an administrator level—they no longer controlled or operated their once monopolised sea routes. As Nigel Costley (2014:39) highlighted, ‘East Indiaman’ has been the favoured label for *Edwin Fox* but argued it was ‘the most imprecise’ term for ships built or traded in the East. Whereas when looking at the ship through construction and technology lenses, the ships themselves change over time without being noticed by the general bystander.

According to Costly (2014:39) true East Indiamen are defined as ships of the seventeenth to early nineteenth centuries that reflected prestige and superiority governed by their respective company and armed in times of war. This definition, however, is too narrow in focus as it describes outward stylistic traits and carrying armament only. As a result, the label implies design and constructional changes were non-existent; however, they did occur. Lignified typologies have been used out of convenience or by force of habit, which is avoided for this study (Zwick 2013:46). Thus, the use of the term East Indiamen to describe the ships is not a true reflection of colonial merchant vessel development over time. Particularly because ‘country ships’ built in India were trading between Asia and Britain at the end of the eighteenth century. Therefore, this research refrains from creating a new typology for the ships. Instead, it draws attention to the subtle changes in ship design and construction techniques employed in the ships used by and for the company with trade between Britain and Asia.

This research also argues that ship typologies alone are inadequate to offer a detailed methodological approach for examining watercraft performance, cultural adaptability, technological innovation and insight into the minds of their builders. Only through a much larger dataset of BEIC ships can we apply a more accurate and representative typology, if any. Until we do, existing BEIC typologies remain basic in description and should only be accepted in a preliminary way as true representations in a generalised sense.

This research explores the design of ship’s hulls that historically have been labelled East Indiamen. This label can be argued as a form of ship typology that indicates an evolutionary linear design development within the wider, more generalised, history of ship evolution. This study, however, approaches the use of the label, East Indiamen, with caution because the ships do not reflect one group of people in space or time. Using *Endeavour*, HMS *Buffalo* and *Edwin Fox*, this research explores evidence relating to what influenced hull design and construction of the individual ships. As a result, this study explores the human behaviours and decisions behind choice of design and construction technologies.

2.9 Ship archaeology

Frederick Hocker and Cheryl Ward (2004:8) noted that much debate surrounds the theoretical models and approaches used to understand the process of change in shipbuilding. Over a century ago, nautical historians employed a teleological process whereby ship improvements were expressed as moving upward in a linear direction (Hocker and Ward 2004:8). Even historical and scholarly writing reflected evolutionary language and Darwinism to describe ship components with biological analogies—such as skeleton, ribs, skin and backbone (Zwick 2013:48). Although analogies referencing the natural world were used long before evolution was theorised (see Lavery 1981). During the early twentieth century, an evolutionary model was used to interpret technological change and vessels in general, however; the essential flaw in this theory is that '…technological variation is not random but deliberate…' (Hocker and Ward 2004:8).

An early study by Olof Hasslöf (1972) argued that construction methods were determined by the shipwright's mastery to form the shape of the hull while retaining structural integrity, not by simply choosing a particular type or method of construction. Hasslöf (1972:42) suggested the inclusion of traditions, concepts, methods and constructions in ship studies for a better understanding of the transition in construction. In 1976, Keith Muckelroy (1976) took the first scholarly step towards understanding site formation processes acting on shipwreck sites and identified cultural and environmental factors that would impact the archaeological record. Richard Gould (1983) expanded beyond the site-specific studies and argued for a cross-temporal and cultural approach to further understand material culture. This approach set the theoretical foundation for developing concepts and theories within the discipline of maritime archaeology.

Specific to nautical archaeological research, Richard Steffy referred to his ship hull studies as the 'philosophy of shipbuilding' (Hocker and Ward 2004:1). Steffy's (1994) book, *Wooden Ship Building and the Interpretation of Shipwrecks*, laid the foundation for nautical archaeological research with examples of the reconstruction of the Kyrenia and Serçe Limanı shipwrecks. His conceptual approach went beyond examining the ship as a whole and instead looked at the underlying reasons that influenced the vessel. Using this approach, he examined the timber hull remains for form, dimensions and tool marks to gain an understanding about the individual shipwright's assumptions, biases and technical knowledge (Hocker and Ward 2004:1).

Theoretical development towards understanding changes in ship construction have differentiated between design (the hull) and building methods (the construction process) (Pomey et al. 2012:235). This approach has been applied to ship studies before, specifically the study of shell-first to skeleton construction methods in the Mediterranean (Basch 1972; Casson 1963; Hasslöf 1972; Pomey 1994, 2004). Seán McGrail (1997) employed this approach by suggesting new forms of hull types after identifying the hulls were of mixed construction. Classification criteria was then later introduced by Hocker and Ward (2004:6), where they defined design, assembly-sequence and structural philosophy. Pomey et al. (2012:236) later agreed with this development and adopted this new approach and shifted the shell and skeleton definitions under 'structural concept'.

Kevin Crisman's (2004; 1984) research on vessels used on Lake Champlain identified adaptations in vessel design influenced by the surrounding environment. He approached his research by combining the historical record with the archaeological record in order to gain a better understanding. Specifically, he investigated the processes by which people adapt or create transportation technologies for the development of vessel types and trade patterns (Crisman 2004). Crisman's (2004) study moved beyond the particularistic approach to exploring external reasons that were driving shipwrights to adapt new designs and technologies.

Pomey et al. (2012:235, 305) stated that the architectural system in relation to the shape of the hull is significant for understanding the various traditions of construction in which transition took place and employed the phrase 'transition in construction' to describe changes in shipbuilding techniques and traditions. The authors applied this approach to the study of understanding the transition from shell-first to skeleton construction (Pomey et al. 2012). This level of thinking is still appropriate for other ship studies. In the case of studying design and construction changes in British East India merchant ships, it is important to understand the principles behind the vessels' assembly while documenting the building process. Therefore, investigating external factors such as society, economics, geography and the environment are important for understanding how vessel construction is influenced. When simplified, these factors fall under the categories of hull-shape, building process and structural concept. This aids the researcher to examine ship construction and reveals basic changes in the principles relating to ship design, hull-structure and construction methods (Pomey et al. 2012:236).

Zwick's paper (2013), 'Conceptual evolution in ancient shipbuilding: An attempt to reinvigorate a shunned theoretical framework', is a critical analysis of past nautical archaeological endeavours to understand vessel evolutionary lineages and typologies. In addition, the paper stresses that theoretical frameworks must remain flexible enough to facilitate a more objective view on the growing data from shipwrecks (Zwick 2013:46). The complete scientific value of shipwrecks, however, cannot be fully explored because these studies are perceived to be too technical to be included in the field of archaeology (Gibbins and Adams 2001:283; Zwick 2013:49). Zwick (2013:49) argued the only way to gain insights into shipbuilding traditions is by recording construction features. Not only does this approach result in revealing information about shipbuilders but it also reveals other aspects relating to timber industries, prestige of vessel and owner, quality of materials, the vessel's purpose and shipping routes based on evidence relating to foreign repair techniques and the use of imported resources (Zwick 2013:49). Such information allows us to understand shipwrights' behaviours, adoption of technologies and influence on hull design and assemblage.

Between shipyards, and even shipwrights working in the same yards, variation in design and construction processes can be expected. Zwick (2013:49) argued that shipwrights were limited in access to resources, skills, rights and blueprints, and as a result could not implement a method of standardisation. Importantly, regardless of standardisation, Zwick (2013:49) continued by stating that even if ships are built with the same traditions, they will still have differences. This is important to recognise for this study into British East India merchant ships because we need to understand the invention, transmission and adoption of new technologies on a human level. Falling short of this analytical process forces ship studies into determining historical 'types' which implies again a lineage of vessel development with no allowance for nuanced shipbuilding practices (Zwick 2013:49). Zwick (2013:46) stated that the use of evolutionary theory for conceptual lineages, especially in nautical archaeology, is highly contested because it infers one vessel type that progresses in a linear form of development.

As Zwick (2013:50) highlighted, there are limited historical sources to identify place of construction in the study of ancient boats and ships—since the wrecking location does not always indicate the origin of the vessel (see McGrail 2015:196–197). Limited information pertaining to where the ship was constructed makes it difficult for the researcher to ask questions relating to variation within shipbuilding processes. Pomey et al. (2012) posed the question on how historical contexts could be interpreted when there are limited written sources and whether shipbuilding processes were isolated or related acts of diffusion from the geographic regions of the Atlantic to the Mediterranean? Which he wrote, 'There is no simple answer…' because two different ship types created in different yards increased variability (Pomey et al. 2012:305). This demonstrates that the inclusion of different vessel types creates a more complex dichotomy. Therefore, the study of one vessel type, such as the British East India merchant ship, is an opportunity to concentrate on understanding the transfer of knowledge, the hull design, methods of construction and influences in relation to the entire shipbuilding sequence within a single colonial culture.

By applying these concepts to the study of *Endeavour*, HMS *Buffalo* and *Edwin Fox*, we gather new insights into global colonial shipbuilding practices during the eighteenth and nineteenth centuries. This study which focuses on British East India merchant ships, allows for the researcher to explore historical records and previous literature to establish the place of vessel construction. Furthermore, historical and archaeological investigations extend into examining the external factors which contributed to ship design and construction technology variation.

Jonathan Adams (2001:303–304, 2013:22–28) went a step further using a holistic approach and suggested variables when investigating ships in order to reveal insights into their manufacture and the societies that created them. Using a holistic approach, however, requires a large dataset in which research questions can move away from a functionalist approach detailing change, to asking ‘how’ and ‘why’ (Adams 2013:51). For his study of medieval and early modern European ships, Adams (2013, 2017) has a suitable dataset through which to explore vessels in a much more general way, whereas this study of British East Indiamen is still limited to establishing a database to allow for expanding the research corpus.

Another interesting approach to ship studies has been the ‘narrow-focus’ on ships and their failings. Investigating why ships fail—put simply, shipwrecked—it guides some researchers to focus on the faults of the shipwright. Before analysing ship data, we need to consider how the failure of a vessel reflects the parent society and whether the database is bias towards failures (Zwick 2013:56)? If so, such studies would be directed to make negative judgments on that shipbuilding tradition and society. For this study, however, all three primary case studies have historical accounts that do not reflect a shipwrecking event caused by defects in the construction and therefore contribute to removing any negative bias towards the vessels’ construction.

In recent decades, ship studies have been seen as reflections of their particular time and place, which is an important concept when interpreting external influences that may affect variation (Hocker and Ward 2004:8). Questions relating to the finer-grained processes for the transmission of knowledge and skills are crucial to understanding continuity and change within shipbuilding traditions (Zwick 2013:57). Researchers have been critical about tracing shipbuilding traditions through construction features (Zwick 2013:60). It is argued that what might be considered as a diagnostic feature may not necessarily identify a tradition because the same feature or method of construction can be found elsewhere without having any contact (Zwick 2013:60).

More recently, vessels have been studied through a vernacular research lens. Amanda Evans’ edited book (2016), *The Archaeology of Vernacular Watercraft*, combines several examples from the North American region and there is a strong focus on demonstrating the concept of vernacular as being dynamic. In this volume, Brad Loewen (2016) explores aspects relating to the transmission of ideas and manifestations of cultural identity as recorded in vessel form using Basque *txalupa*/*chalupa* (shallop) boats found in Canada as examples (see Ford et al. 2018). When applied to ship studies, Amanda Evans and Sheli Smith (2016:2) argued that research frameworks must consider ships through cultural ecology, and should include technologies, social needs and ideology, because vernacular craft are considered cultural phenomena.

The analysis of variability relating to ships can include, but is not limited to, materials, dimensions and methods of construction (Maarleveld 1995:6). Archaeological investigations of ships should be broken down into these components of variability in order to analyse the differences rather than the similarities. As a result, researching ships beyond typology contributes more to our understanding about human decisions influencing technological changes and development of watercraft. Therefore, this research explores shipwright behaviours through the analysis of individual ship components and technologies.

Specifically, this study focuses on global British merchant ships that operated on the East India trade routes during the late-eighteenth to mid-nineteenth centuries. Furthermore, the investigation of archaeological data and historical records provide detailed analyses pertaining to technological change within these vessels. Inferences determined from this study provide a foundation from which other studies can expand on our knowledge relating to British colonial merchant shipbuilding in domestic and foreign settings.

2.10 Shipbuilding

Other nation's EIC ships have also captured the attention of archaeologists. Major studies include those by Wendy van Duivenvoorde (2008, 2015a), on seventeenth-century Dutch East Indiamen, and Filipe Castro (2001, 2003), on a seventeenth-century Portuguese Indiaman. They both examined hull remains and provided conclusive evidence relating to the construction of early European East Indiamen. These studies, in conjunction with this project, will contribute to our understanding of European based ship design and construction processes in a global context.

More generally, but still within the scope of English shipbuilding, previous archaeological studies relating to English ship construction during the same period have focused predominately on naval vessels. Kroum Batchvarov (2002) researched the framing of seventeenth-century English men-of-war and Dan Atkinson (2007) researched shipbuilding and timber management in the Royal English dockyards between 1750 and 1850. These previous studies, however, are still applicable to merchant studies as they can inform the researcher about national naval shipbuilding practices that may have been incorporated into or adopted from domestic merchant design.

To understand the influence shipwrights had in shipyards, this thesis includes a review of notable shipwrights in the English shipbuilding industry. Sir Robert Seppings (1767–1840) was a master shipwright at the Chatham Dockyard in 1803 (Walker 2010:41). He is best known for introducing shipbuilding reforms that included addressing diminishing stocks of long timber, rot in timber structures, addressing structural problems caused by racking[2] in a seaway[3], and introducing the round bow and the round stern allowing better gun positioning in naval vessels (Walker 2010:41).

In the early-nineteenth century, oak used for ship construction was in short supply and supplies from Europe were being blockaded by Napoleon Bonaparte (Walker 2010:38). This forced the British to seek a timber supply elsewhere and Malabar teak was identified as of great technical quality (Walker 2010:38). As a result of the rise in the number of ships being constructed in Britain, the demands on local timber suppliers were reminding them of the risk of the new teak supplies becoming endangered (Walker 2010:38–39). Teak had many advantages over oak, including, less splintering when hit by cannon fire, less corrosion on metal fastenings, shorter seasoning and was expected to increase the operating life of ships (Walker 2010:39). Furthermore, ships built in Bombay using Malabar teak were regarded as 50 per cent

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[2] Racking describes the distortion on the ship's hull in a transverse direction. In rough seas, the deck can move laterally relative to the keel and one side of the ship can move vertically relative to the opposite side.

[3] Seaway is a rough sea or ocean to sail through.

superior to vessels built in Britain, with the timber considered to be the most valuable in the world for shipbuilding (Spence 2015:73; Walker 2010:39).

Interestingly, Robert Seppings introduced the use of diagonal planking on decks and other parts, which allowed for shorter length pieces to be used in the construction of the hull (Walker 2010:42). This development was continued and applied to the floors and produced a system that increased strength and resistance to the flexing of the hull (Walker 2010:42). To combat the racking phenomenon, Seppings introduced iron hanging and lodging knees in place of the more traditionally grown timber knees (Walker 2010:42). These innovations reduced the effect of hogging and sagging from dry-docking to afloat by 50 per cent (Walker 2010:42). During this period, Seppings's tenure was full of innovation to address the growing shortage of raw materials. He improved methods of timber storage and experimented with the scarfing of timber joints (Walker 2010:42). It is these improvements that can be identified and examined through the archaeological recording of ship components, thereby providing new insights into technical adaptations or not within merchant fleets.

Another documented shipwright, Jamsetjee Bomanjee Wadia (1754–1821), who worked in the Bombay Dockyard, Mumbai, became a master shipwright for the East India Company in 1736 (Walker 2010:37–38). Bombay dockyards were established by the British in response to rising conflict tensions c.1707 (Kochhar 2008:2005). Ships in the yard were constructed for the Bombay Marine, the British East India Company and commercial owners (Walker 2010:38). Although, he never constructed ships in Calcutta, details about his Mumbai shipyard are useful for drawing more general inferences about the social dynamics within an Indian shipyard during the eighteenth century (Kochhar 2008:2006; Neale 2013:528–529; Walker 2010:38; White 1987:191).

Indrajit Ray has published several books and articles describing shipbuilding in Bengal during the industrialisation period in India (1757–1857) (Ray 1995, 2011, 2016). Specifically, he describes timber resources, methods of construction and philosophises over the art of Bengali shipbuilding. Another useful resource is John Phipps's (1840b) *Collection of Papers Relating to Shipbuilding in India*. In particular, entries by A. Lambert (1840) and J. Kyd (1840) offer insights into timber used for shipbuilding and on the industry itself during the 1810s, such as selection and milling.

More generally, other publications present details about factors influencing shipyards in India. In Amalendu Guha's (1970b) paper, he discussed the interconnectivity the Parsis had with the British. T.M. Luhrmann (1994:336) stated that the British were eager to have Parsis in Bombay for their shipbuilding skills. Notably, Parsee shipbuilders were constrained under colonial rule and could not operate as independent capitalists (Guha 1970a; Timburg 1973:32). Guha's paper focused on the Bombay region but still adds insight into local shipbuilding techniques (Guha 1970b:M-109). More generally, G.V. Scammell (2000:526) noted that the Indian shipping industry was impacted by growing Western competition in the nineteenth century. These insights into Indian shipbuilding methods are useful for this study for understanding cross-cultural transfer of knowledge and techniques when building foreign designed ships with domestic resources and skill.

One incident in the yard happened when a Royal naval officer flogged a Parsee worker, which led to unrest in the yard (Kochhar 2008:2006). As a result, a formal agreement between the British flag officers and the shipbuilders was made that the Master shipwright was the sole person in charge relating to the workforce (Walker 2010:38). The significance of this agreement demonstrates that the Parsee shipbuilders commanded authority and respect over their yards. Due to the Parsis' shipbuilding skills and expertise, seven generations of Wadia family members worked for the British in the Wadia Dockyards (Neale 2013:528–529; White 1987:191).

Details from these documents provide literature identifying social, economic and the political factors relating to Indian shipbuilding yards that offer insight into influences on construction processes. Samual Berthet's (2015) paper titled, Boat technology and culture in Chittagong, discussed maritime practice in the Chittagong region. He argued that a multi-disciplinary approach-based survey to patterns of shipbuilding and trade is yet to be explored, while investigating shipbuilding practices through trade routes, navigational techniques and related culture (Berthet 2015). Notably, Berthet (2015:181) says studies of shipbuilding in South Asia are influenced by European shipbuilding and maritime history. Relating to this study, he points to the survey of ships as being influenced by various factors, including: geographic, socio-political and economic practicalities and the skill, knowledge and aesthetic sense of the shipbuilder (Berthet 2015:189). As a result, ships' shape, size, design, materials and techniques are a consequence of these factors (Berthet 2015:190). With the introduction of British shipbuilding techniques, local shipwrights were quick to adopt, so much so that British merchants preferred colonial-built ships for their quality and ingenuity (Berthet 2015:190).

Indrajit Ray (2016) argued that the quality of raw materials and ship artisans in Bengal helped the local shipbuilding industry stay internationally competitive. Notably, when consulting shipping register data between 1781 and 1839, he points out that the life expectancy of ships constructed in Bengal was more than 20 years compared with the 11 to 12 years for British ships (Ray 2016:3984). The Bengal teak-built ships were seen to be superior to their English oak and fir counterparts (Ray 2011:188, 2016:3984). Furthermore, he highlighted that the Indian shipbuilding tradition worked without blueprints and relied on the dexterity and skill of the workers (Ray 2016:3984). Berthet (2015:194) also identified a lack of research in relation to seagoing ships in unified Bengal[4]. This study investigates what European style vessels built in Calcutta, namely HMS *Buffalo* and *Edwin Fox*, contribute to our understanding about larger maritime fleets.

2.11 Conclusions

This research employs a behavioural approach and framework, which constructs a deeply contextualised and nuanced explanation relating to technological change seen in British East Indiamen during the eighteenth and nineteenth centuries. In addition, ship typologies are no longer privileged and forward linear progressions of development are no longer considered appropriate. Rather, by analysing each ship individually, it is possible to contribute new understandings about the societies and technologies that were intertwined to build BEIC ships. Using archaeological

[4] Bengal was divided in 1905, reunified in 1912 and partitioned in 1947—East Bengal was renamed as East Pakistan until Bangladesh became independent in 1971 (Berthet 2015:181).

evidence and historical sources, this research is the first to explore British colonial shipbuilding in both foreign and domestic contexts and to explore how national and international factors influenced ship development. In terms of past human behaviour, this research considers social, political, economic, cultural and environmental factors to understand the decision-making processes made by shipwrights when constructing BEIC vessels. Furthermore, the application of cultural transmission theory and behavioural technology frameworks to nautical archaeological studies enhance our understanding of shipwright learning behaviours and allows us to consider to what extent these behaviours influenced ship development during the eighteenth and nineteenth centuries.

Chapter 3. Contextualising the past

This chapter synthesises the historical background relating to the Company's shipping and contextualises the socio-political eighteenth and nineteenth centuries for this study. The historical backgrounds of the three primary case studies are included here to provide historical context to their origin, sailing careers and why they are available to be studied. Additionally, the East India Company has been the focus of historical research in the past, whereas this study focuses on those ships that were used in the global trade (see Barrow 2017; Dalrymple 2019; Keay 2010).

3.1 Defining terms

The East India Company is known by different names. The Company of Merchants of London to the East Indies and the 'Old' and 'New' Companies reflect the origins of the company before it was finally merged into the United Company of Merchants operating under the charter of 1698 (Kaye 1853:122; Keay 2010:14; Sutton 2000:155–156). In literature, however, several other names also refer to the same enterprise. These include the Honourable East India Company (HEIC), the East India Trading Company (EITC), the English East India Company (EEIC), then the British East India Company (BEIC) and more generally, the John Company and The Company (MacGregor 1985:23; Miller 1980:14). The names mostly reflect new charters, the merging of syndicates and more generally, the trade with the East.

England's political boundaries altered with alliances throughout the sixteenth to early twentieth centuries. In 1536, England and Wales joined territories and were ruled as the Kingdom of England (Jenkins 2007:131 and 146). In 1707, Scotland and the Kingdom of England became the Kingdom of Great Britain (Speck 1993:18). When the Kingdom of Ireland was united with the Kingdom of Great Britain in 1801, the United Kingdom of Great Britain and Ireland was formed. This unification lasted until 1922 when the Irish Free State was formed and subsequently created the Republic of Ireland and Northern Ireland (Hachey and McCaffrey 2010:144). Thus, the union of British states became known as the United Kingdom of Great Britain and Northern Ireland.

3.2 The Company

Through the processes of colonisation, existing nations and their peoples experienced violence and oppression. Colonialism, backed by a capitalist system, exploited land, labour and resources in so-called ‘new’ territories (Burke et al. 2016:145). It was under these pretences that the British East India Company took advantage of foreign resources to create wealth. Thereby, ships served as vital links between wider geographical markets and ensured colonisation succeeded.

On 31 December 1600, Queen Elizabeth I issued the first charter permitting a syndicate of English nationals to trade with Eastern countries. The newly formed ‘Company of Merchants of London to the East Indies’ ordered the first fleet of vessels to depart in 1601 and formally commenced centuries of trading. Continuing until 1621 the Company of Merchants exported wool, iron, lead, tin and other products from England with a value c.£319,211. On return the Company purchased goods c.£375,288 and sold these cargoes in England for c.£2,044,600—making the voyages highly profitable (Chatterton 1912:79). In the first 12 voyages the Company’s average returned profit was 138 per cent (Chatterton 1912:80). These voyages took up to two years with their full financial returns only realised after three and four years. Albeit when the profits are averaged out per year, the Company returned approximately 20 per cent (Chatterton 1912:80). This made the Company incredibly attractive for outside investors seeking to take a share in the profits.

In 1657, Oliver Cromwell conferred a new charter which established the Company as a joint stock business (Sutton 2000:156). This allowed outside investors to actively participate in any profitable return made by the Company. Then by 1688, other syndicates looked to break the trade monopoly and operated their own fleet of ships. This effectively created what is known as the ‘Old’ and ‘New’ Companies. This rivalry continued for the next 20 years, when between 1707 and 1709 the ‘Old’ and ‘New’ companies merged creating the United Company of Merchants (Barrow 2017:viii; Sutton 2000:156). The merging of the two companies effectively recreated the monopoly that was broken up 20 years prior and now held the sole right to trade with the East for its foreseeable future.

The Company then continued trading with its monopoly until 1813 when the new charter was amended (Barrow 2017:viii) . By the nineteenth century the Company had established trade routes reaching India, South East Asia and China (Figure 8). A return voyage would see the vessels sail a loop from Britain to the East via the Cape of Good Hope with sailing times dictated by the monsoon seasons. Then in 1833–1834, the Company lost its monopoly, in particular its trade to China and ceased its commercial operations (Barrow 2017:viii; Kaye 1853:135; Sutton 2000:156). Finally, in 1874 the Company's final charter expired, ending 274 years of operation.

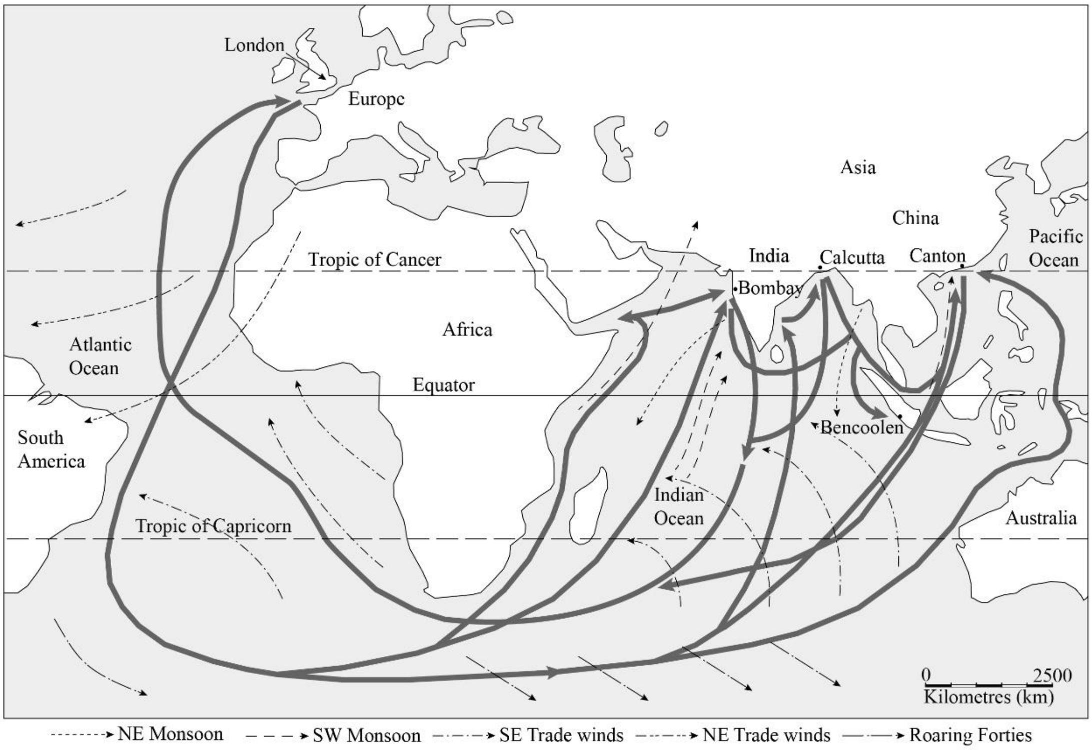

Figure 8. The established trade routes of the Company during the eighteenth to nineteenth centuries (after Barrow 2017:XVI and XVII; Sutton 2000:25).

3.3 East Indiamen

In the beginning, the Company chartered ships for trade, but decided to buy and own their own vessels. This was in response to private ship owners charging the Company exorbitant prices. The Company then sought control of its ships and by 1621, it owned 10,000 tons of shipping (Mehta c.1923:10). Managing their own fleet, however, came with operating costs, such as the building and maintenance of ships and dockyards, which reduced maximum profit (Chatterton 1912:79). While it could be argued the Company's control over the shipyard outweighed economic sacrifice in profits, ultimately the in-house shipbuilding operation proved too costly. The yard with all the employees and supplies absorbed too much capital and it was found that the hiring of ships was more economical (Chatterton 1912:88). This in turn created a tendering process for ship owners to participate in the Company's trade.

Ships chartered for the Company had by the eighteenth century been tendered to private owners for their construction and proprietorship. With the formation of the United Company (1707–1709), the power of building a ship shifted to the vessel's private owners, the husbands and to the person or persons to whom permission was granted to replace a ship (Sutton 2000:21). The British East India Company reused ships in terms of replacing them without creating increased Company ship tonnage. The term 'on the bottom of' also known as 'hereditary bottoms' describes the owners' rights to supply another ship in replacement of the one that has worn out (Chatterton 1912:183). This process to control the overall supply of ships charted to the Company was directed by the economics of the enterprise. It ensured an efficient fleet, whereby the Company governed a fleet that was always ready and constructed to their principles. The Company's surveyors inspected the ships to strict standards and the ships in turn were commanded by officers of good 'character, talents and experience' (Chatterton 1912:184). In 1796, the right to build on a ship's bottom was abolished and opened opportunities to increase ship tonnage, therefore allowing the volume of trade to increase (Cotton 1949:49).

The ship's husband played a vital role in liaising with the Court of Directors on behalf of the ship's owner. A ship's husband was required for orchestrating the agreement to build a new ship on the bottom of previous ships on behalf of the owners. Once the contract was awarded, the husband managed all affairs during the building process. The husband ensured all accounts with suppliers and the ship builder were settled, contractual agreements were met, insurance was paid, the crew were paid their advanced money and all accounts with the Company were settled (Sutton 2000:22). The husband acted alone in managing the build and exercised complete freedom over all aspects of ship business (Sutton 2000:22).

The ships employed in the Company’s service are regarded in popular perception as being large, grand and superbly built (Sutton 2000:37). In the seventeenth century, the ships themselves were originally chartered from various owners, then constructed for the Company, and reverted to the hiring of vessels built with private investment. By the eighteenth century, the right to build a ship was advertised through a tendering process with various authorities maintaining control. The Company also specified vessel dimensions and stipulated measurements within their tender contracts. By the end of the eighteenth century, the Company controlled how big the finished product should be while external powers began influencing ship design. The Company’s ship surveyor, Gabriel Snodgrass, advocated for and enacted several technological and design changes to improve the ship’s hull (Figure 9) (MacGregor 1985:23–24). Notably, he suggested increasing the thickness of bottom planks to reduce the need for repair and subsequent timber consumption. He also introduced iron bracing in the ship’s hulls and improved ship stability by adopting design elements he had seen in India while he had been stationed there. Then, by the early nineteenth century, the Company ships adopted new technologies to improve performance, while staying largely similar in design to their late eighteenth century counterparts (see MacGregor 1985:173–208; Sutton 2000:37–52).

3.4 Working with wood

Timber was a critical resource for ensuring the Company’s economic success. Without quality timber the Company had no ships to transport its cargoes. The natural product is one of the best suited for shipbuilding, although it is not without its disadvantages. The constant threat of fire and shipworm plagued a vessel’s success (Moll 1926:357). One of the biggest threats, however, was dry rot. Unseasoned, diseased, or young timber with porous textures were susceptible to dry-rot. Equally, seasoned wood was found to also be prone to dry-rot where conditions consisted of damp stagnant air (Blackburn 1817:150). People had not yet made the connection between fungal growth and dry rot.

Figure 9. Line engraving on paper depicting Gabriel Snodgrass, 1719–1799, shipbuilder and surveyor to the East India Company (Drayton 1799).

Shipyards, timber merchants and purveyors worked to developed different methods for preventing future decay. It was believed that felling a tree by season would help to stave off dry rot. In Britain, it was thought it was best to fell a tree in the winter months to avoid the sap wood in the spring and summer months (Moll 1926:360)—with Gabriel Snodgrass agreeing (1797a:49). To test the seasonal felling theory, the British Admiralty launched the corvette *Hawke* in 1793 constructed of one half of spring timber and the other half of winter timber (Moll 1926:361). After the breaking up of the ship in 1803, there was no difference in quality, ‘all timber was perfectly rotten’ (Moll 1926:361).

In comparison, and around the same time, it was thought in India that timber should ‘...be felled during the decline of the moon...’ due to the belief that there would be a decline in sap (Phipps 1840a:80–81). Additionally, forests in Moulmain were used for procuring teak from the people of Burma (Myanmar) who were contracted to fell the trees (Phipps 1840a:57). The trees were prepared for felling by cutting into the bark (all around) and left in that state until all the sap had run out. This meant the tree died and was left standing for a further two years before being cut down. This ensured the tree retained as little moisture as possible—otherwise it was worth less on the market (Phipps 1840a:57).

Felling a tree was not the only time shipwrights and ship owners battled with the threat of dry rot. The British Admiralty experimented with different methods of seasoning the timbers. Various methods were applied to the seasoning of timbers from stacking in the yards to leaving the ship sit on its stocks for a duration. In eighteenth-century Britain, it was recommended that planks should be sawn and stored in sheds along their edges with sticks between them for at least one year before their use (Warren 1791:19). It was thought that the ship’s keel, frames, stem and stern post should stand exposed to all weather for one year while the planks and other timbers remain separate to season (Warren 1791:19). This, however, meant the ships structure was rotting while the planks were seasoning.

Compared to practices within the British East India Company, Gabriel Snodgrass wrote the following insights:

> No ship was ever built entirely with timber that had laid to season three years, two years, or even one year; consequently, that part of the ship which was formed of the most unseasoned wood must be expected to decay first and thus a progressive decay in the several parts of the ship, subjects her to the necessity of continual repairs, at an immense expense and to the great detriment of the service (Snodgrass 1797b:2).

He recommended 'leaving the tree-nail holes open for air until the ships were nearly finished and ready for caulking…' (Snodgrass 1797b:4). This advice helped season the timber before finishing the ship as was similar practice to what the Admiralty recommended. It is clear by the end of the eighteenth century, the British East India Company was likely constructing ships with a mixture of green and seasoned timber.

In Britain, purveyors were tasked with purchasing wood and storing it in the Company's private timber yards at Reading. When required, the timber was placed on to barges and transported along the Thames River to the shipbuilding yards where they were remeasured and marked (Chatterton 1912:81–82). The Deptford Yard maintained large stocks of 'timber planckes [planks], sheathing-boards and treenayles [treenails]' (Chatterton 1912:81), whereas in India, superintendent Robert Anderson described elephants as being used to pull the timbers to the rivers (Bulley 2000:95–96). It was not ideal for the timber to be floated down rivers as it would become much heavier—and possibly unnecessarily increase the time needed for seasoning in the yards (Bulley 2000:96).

At the end of the eighteenth century, ships became larger in response to increased trade. The Company then required all ships to be contracted for six return voyages to India or China (Chatterton 1912:186). By 1803, the Company was demanding ships to sail an additional two voyages making it eight in total. This innovation was made possible because the new ships built in the early nineteenth century 'could be repaired and refitted…with great advantage' (Chatterton 1912:186). Furthermore, it was seen by the company that fewer ships constructed would lessen the consumption of ship timber (Chatterton 1912:186).

During the 1790s, teak was gaining acceptance as a durable timber for use in a ship's hull. Teak forests along the Malabar Coast were being used for colonial shipbuilding (Bulley 2000:94). Teak selected for shipbuilding was harvested from forests to the north of Bombay, Gujarat, Cutch and Cambay. It is said that the forests of Ghir in Gujarat provided good crooked timber (Figure 10) (Bulley 2000:94). Straight timbers for Calcutta were harvested in Bombay, Gujarat, Konkan, Canara, Travancore, Cutch and Cambay, but the majority of these forests were decimated due to mismanagement (Bulley 2000:29). Demand for the timber was unmatched and there was little concern for preservation of supply, with these areas not being regulated by British jurisdiction or treaties until 1818 (Bulley 2000:94).

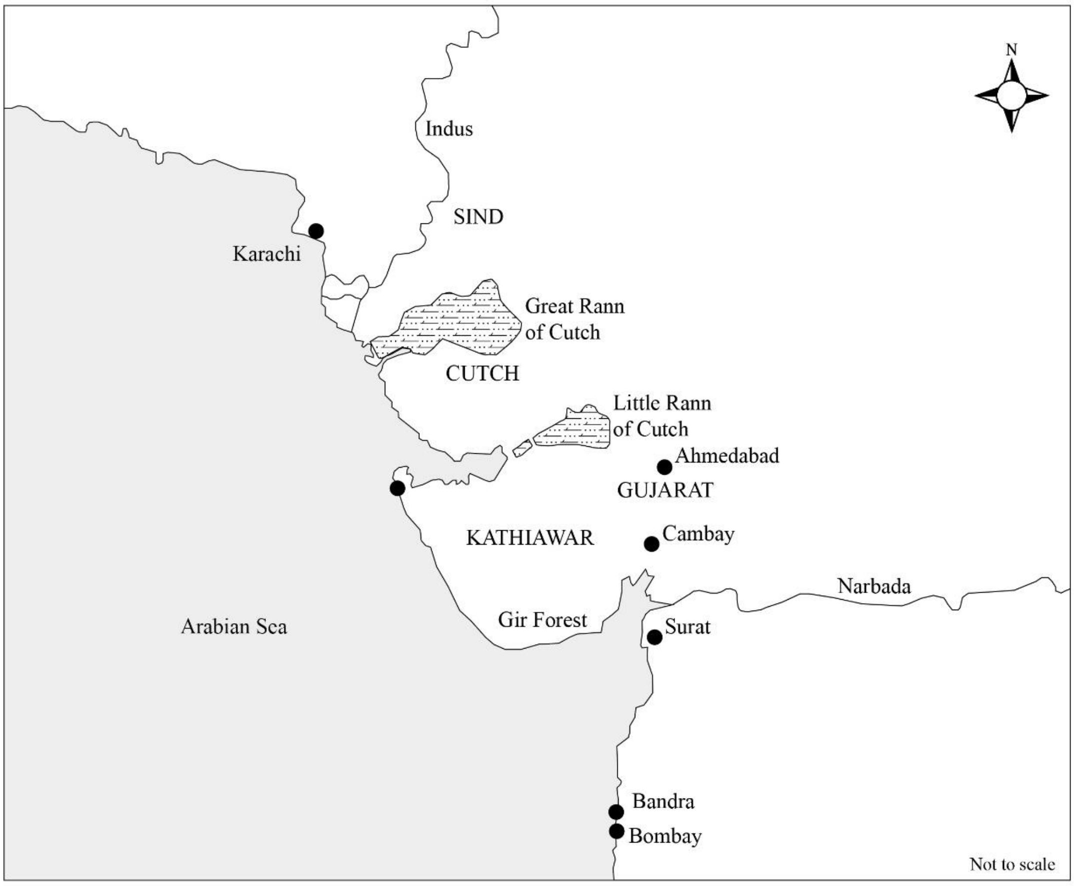

Figure 10. Some of the forests north of the Malabar Coast (after Bulley 2000:xiv).

During the end of the eighteenth and the beginning of the nineteenth centuries, Britain's demand for timber increased. The Napoleonic Wars in particular, demanded ships be built with 'greater care' and 'armed as strongly as ever' (Chatterton 1912:186). As a result, the costs of building ships during war time greatly increased. This localised investment influenced the British in considering teak as a favourable shipbuilding resource (Bulley 2000:94). Shipbuilding facilities in Bombay and Bengal started to be established towards the end of the eighteenth century (Bulley 2000:28). Calcutta relied on sources of teak from Pegu and other timbers from Chittagong and Bombay, although Pegu teak was not considered of superior quality to that of Malabar teak (Bulley 2000:29). The only forest that was still able to meet the demand of the Company at the beginning of the nineteenth century was Travancore (Bulley 2000:29). A detailed description of timber procurement in India during the nineteenth century is documented (see Phipps 1840a:45–86).

Around the beginning of the nineteenth century, supply chains of teak timber appeared to be in disarray (Bulley 2000:94–97). War during 1803 again put pressure on teak stocks. The Marine Superintendent, Robert Anderson, identified Cochin as having large timbers (Bulley 2000:95). If the procurement of timbers was unattainable, however, the Company was to be advised of a resource shortage (Bulley 2000:95). Through the combination of war, local transport availability, monsoon seasons and access to supply, shipbuilding was often delayed. By the 1810s, the forests of Malabar were ‘plundered’, and the Bombay Council eventually realised that controls needed to be enacted to preserve the once perceived ‘inexhaustible supply’ (Bulley 2000:97). An embargo had been enacted in 1813 and continued in 1815 on the import of timber, further guaranteeing the control by the Company over teak supply (Bulley 2000:97).

During the end of the eighteenth century and the beginning of the nineteenth century, timber demand for the building of the Company’s ships greatly increased. The demand caused by external factors forced the Company to seek and adopt foreign timbers in their vessel’s construction. Additionally, forests were decimated through mismanagement and the continued threat of dry rot plagued the shipbuilding industry.

3.5 The East Indiamen: Overview and background

In terms of written histories specific to the East India Company, Jean Sutton (2000, 2010) has compiled the most complete historical account of the Company and its ships. Using archival research, she explored all facets of the Company’s history including, ships, shipbuilding, cargoes, owners and crew. Specifically, she described the shipbuilding process from laying the keel to regular maintenance and repairs

(Sutton 2000:37–42). While she identified changes in designs and materials over time in English, and later British, shipyards, she stopped short of comparing domestic shipbuilding practices with those practiced in colonies such as India. This research explores this area of transnational shipbuilding practice and investigates what influenced ship development across two geographic regions. Such a comparison will provide context to understanding the archaeological and historical remains of *Endeavour*, HMS *Buffalo* and *Edwin Fox*.

Ships operated by the Company had several different classes of their own. This was because ships were employed by the Company to operate trade routes, whether they were open ocean or servicing local domestic ports. Largely, the English/British East India Company opted to not own its ships. It instead tendered for their construction and chartered the vessels from independent groups of investors and ship owners under the direction of a ship's husband (Browne 2014:22). These were usually the larger vessels that sailed across international waters between countries. Whereas, country trading vessels were typically ships owned, managed and captained by local Indian populations or British residents in India (Ball 1995:29). Nevertheless, all private traders had to be licenced and registered with the Company, ensuring the enterprise's monopoly on trade (Ball 1995:29).

3.6 English/British EIC archaeological ship studies

This study is one of many to investigate and record ships employed in the English and/or British East India Company's service. Over the past four decades, previous investigations of Company ships have included site surveys and excavations. Listed below in the order of date constructed or launched, the following describes vessels by site recording, site remains specific to hull structure and whether they are appropriate for inclusion within this study. The ships that complement this research are revisited in the discussion chapter and assessed alongside the three primary case studies selected for analysis in this thesis.

3.6.1 *Trial* (built c.1621)

Trial (or *Tryall*) departed England on 4 September 1621 to sail to the East Indies in service to the English East India Company (Green 1977:1; Henderson 1993:27). In

May 1622, while sailing up the north western coast of Australia, *Trial* wrecked on a reef as a result of navigational error (Green 1977:1)—the reef subsequently being named after the ship. This wrecking event labelled *Trial* as Australia's earliest known European shipwreck and the earliest English East Indiaman to be found in Australian waters (Green 1977:1).

The wreck site is exposed to large surges and bad weather which can prevent diver access to the site (Green 1977:44). Due to the hydrodynamic location and possible destructive cultural processes, only metal remains were recorded (Green 1986:196). These included iron cannon, anchors, scraps of lead sheeting and lead shot (Green 1977:50). These artefacts pose questions, however, about the identity of the vessel and Green (1977) suggests the identification of *Trial* remains tentative only. No archaeological timber hull remains were recorded on site and therefore *Trial* is excluded from this study.

3.6.2 *Avondster* (built c.1641)

At the time of sinking, *Avondster*, sailed under the Dutch flag of the *Vereenigde Oostindische Compagnie* (VOC). The ship, however, was originally employed in the service of the English East India Company (Parthesius et al. 2003:13; van Duivenvoorde 2015a:180–183). It was first named *John and Thomas* and after the EIC bought it in 1641, renamed it *Blessing* (Parthesius 2003:31; Parthesius et al. 2003:13; Sutton 2000:148). In 1652, the First Anglo-Dutch war broke out and in 1653 *Blessing* was captured by the VOC (Parthesius et al. 2003:13–14). Once captured, the ship was renamed *Avondster* and underwent a refit with the galley of Dutch bricks found on the wreck site as archaeological evidence (Parthesius et al. 2003:14). Following the refit, *Avondster* continued sailing around Asia between 1655 and 1657 and finally sank in Galle Harbour, Sri Lanka on 2 July 1659 (Parthesius 2003:30; Parthesius et al. 2003:14–15; Parthesius et al. 2005:219). The exact age of the ship and its dimensions are unknown, however, the length is estimated at between 30 metres and 40 metres and historical records list the size of the ship as 250, 260 and while in VOC service, 360 tons (Manders et al. 2004:1252; Parthesius 2007:136–137; Parthesius et al. 2003:14 and 24; Parthesius et al. 2005:220).

The remains of the ship cover an area of approximately 40 metres long by 10 metres wide (Parthesius 2003:33). In 1998 and 1999 the site of *Avondster* was surveyed and then excavated by a team of maritime archaeologists between 2001 and 2004 (Parthesius et al. 2005:221–222). The excavations revealed the ship's hull structure was complete on one side up to the main deck (Parthesius 2003:36). The remaining ship structure includes components, such as a possible keelson, hull planking, possible sheathing or sacrificial planking, frames, ceiling planking, lodging knees and beams (Parthesius et al. 2005:227–228; van Duivenvoorde 2015a:180–183). These elements provide archaeological evidence towards understanding the construction of a seventeenth-century English ship. It is important to note, however, that due to the unknown construction date and whether it was built specifically for the English East India Company, it is unsuitable for direct comparison to other English East Indiamen for the purposes of this study.

3.6.3 *Griffin* (built 1748)

In 1748, *Griffin* was launched at Perry's yard, in Blackwall on the River Thames (Daggett and Shaffer 1990:61). Its tonnage is recorded as 499 tons but is thought to be more like 600 tons in size and with a keel of 105 feet (32 m) in length (Daggett and Shaffer 1990:66 and 126). *Griffin* and its sister ship, *Boscawen*, was built with a new revolutionary design—flush decks, intended for making the ships sail faster (Daggett and Shaffer 1990:56). To make the decks flush, the fo'c'sle (forecastle) deck was removed. This created a deck that was flush to the quarterdeck doors just behind the mizzen mast. At the stern, there was only one deck instead of two.

The ship became a total loss in 1761 and was relocated in 1987 (Daggett et al. 1990:36). The first timbers were uncovered on 16 December 1987 (Daggett and Shaffer 1990:125). Upon first observations, several pieces measured about eight feet (2.43 metres) in length by one foot (0.3 metres) in width (Daggert and Shaffer 1990:126). At first the wreck site displayed random timbers orientated in all directions (Daggett and Shaffer 1990:126). Then a few days later and after more excavation, the hull was located measuring 96.6 feet (29 metres) in length exposing approximately 66 per cent of the hull remains (Daggett et al. 1990:37; Daggett and Shaffer 1990:126). Substantial components remained including frames that were positioned at right angles and were covered on both sides with a layer of planking.

The outside planking was constructed as a double layer of planks. The Philippines Museum was contacted by the author requesting additional site records from the excavation; however, the records have been subsequently lost over the years (Ligaya Lacsina pers. comm. 2019). During fieldwork, the team created a scaled photomosaic of the hull and dimensions extracted from this are used in this thesis (see Chapter 8).

3.6.4 *Sydney Cove* (built c.1790s)

Although a relatively small company ship, *Sydney Cove* was a country trader constructed in India in the late eighteenth century. Its archaeological remains are useful for this study to examine the possible blending of shipbuilding techniques. Through historical research conducted by Shirley Strachan (1986:97–98), it is strongly suggested *Sydney Cove* was formerly named *Bengum Shaw*. According to Strachan’s research considered together with the archaeological material, the ship was three-masted with a double deck and an overall length of 100 ft (30 m), a maximum breadth of 24 ft (7 m) and 250–300 tons (Nash 2002:40, 2006:10). The ship was classed as a country trader and operated under licence from the British East India Company (Nash 2002:39). In November 1796, the house of Campbell and Clark (private merchants) acquired the ship and renamed it *Sydney Cove* to deliver goods to Sydney, Australia (Muecke 2011:37; Nash 2002:40, 2005:10, 2009:35). *Sydney Cove* shipwrecked near Preservation Island, Tasmania, in 1797.

One hundred and eighty years later in 1977, divers relocated the shipwreck site close to shore on the southern end of Preservation Island (Nash 2002:39, 2005:10). Archaeological surveys and test excavations conducted between 1977 and 1980 identified a surviving hull structure in a 10 m by 40 m area and in about 5 m of water (Nash 2005:10). Following the survey, the area was excavated on several field seasons between 1991 and 1994 revealing 95 square metres of timber structure (Nash 2005:10). This assemblage of timbers included the keel, false keel, keelson, rider keelson, floors, frames and futtocks, outer and inner planking and copper sheathing (Nash 2002:45–47). The detailed recording of the timber hull structure and its individual components revealed insights into late-eighteenth century Indian shipbuilding practices for country traders. As Shirley Strachan (1986) highlighted,

Sydney Cove is a unique surviving example of a particular ship construction showing both foreign European and traditional Indian influences.
Therefore, while no direct comparison can be made between a smaller sized country trader to that of a British East Indiaman, *Sydney Cove* is included in the discussion chapter to provide archaeological evidence to assess similar construction signatures found in HMS *Buffalo* and *Edwin Fox*. This contributes to our understanding of how ships were built locally, using local techniques, knowledge and resources.

3.6.5 *Brunswick* (built 1792)

In 1792, Perry & Company completed the construction of *Brunswick* at Blackwall Yard on the River Thames, London (Hackman 2001:73; Mollema 2015:32). The length of the ship measured 130 ft (39.62 m) at the keel by a breadth of 42 ft (12.8 m) ([BL] 045-001114675). The ship registered between 1,200 and 1,244 tons and was armed with cannon (MacGregor 1985:210; Mollema 2015:32–33; Sutton 2000:153). In July 1805, while sailing its sixth homeward journey, the French ship *Marengo* and its crew successfully captured *Brunswick* and sailed it to Simon's Town, South Africa (Laughton 1902:355; Mollema 2015:35–36). Shortly after arriving, a gale blew and *Brunswick* was driven towards shore, wrecking in the bay on 2 September 1805 (Laughton 1902:362).

The *Brunswick* shipwreck has been the focus of several previous salvage and investigative research and recording projects in the early 1800s, 1967, 1993–1995, 2004 an 2012–2013 (Boshoff 2014:6799; Boshoff et al. 1995; Harding 2013:26; Mollema 2015:37–46; Visser 2004). The most recent project took place in 2014 as part of a Masters degree, in the Department of History, East Carolina University (Mollema 2015). Fieldwork conducted in July 2014 investigated ship construction choices and technologies through the recording and analyses of ship components (Mollema 2017:46; Mollema and Harris 2014:1). Specifically, *Bato* (a Dutch ship, shipwrecked 1806) and *Brunswick* were compared to discuss and compare technology choices between the two nations. Scantling measurements were recorded for *Bato*, however, due to bad weather, comparable measurements were not collected from *Brunswick* (Mollema 2015:60). Instead, the author used *Brunswick*'s averaged scantling measurements from Project Sandalwood in 1995, albeit limited in comparative data (Boshoff 1998).

3.6.6 *Earl of Abergavenny* (built 1796)

Earl of Abergavenny was constructed at the Pitcher Yard, Northfleet, Kent, in 1796 and, when launched on 15 December 1796, it was one of the largest ships built for the trade to China (Figure 11) (Cumming 2002; Cumming and Carter 1990:31). The ship measured 176 ft 11 in. (53.92 m) in length, 143 ft 11 ½ in. (43.88 m) along the keel, 43 ft 8 in. (13.31 m) in breadth and 1,460 tons (Cumming 2002; Cumming and Carter 1990:31). The ship sank in Weymouth Bay in 1805 on its fifth voyage for the BEIC (Cumming and Carter 1990:31).

Figure 11. The '*Earl of Abergavenny*' East Indiaman, off Southsea. Oil on canvas by Thomas Luny (1759–1837), © British Library Board (Foster 59, c13161-18).

In the 1980s the Weymouth Underwater Archaeological Group began directing archaeological surveys and excavations and continued conducting them until c.2000 (Cumming 2002). The project focussed on recovering the cargo and incidentally exposed an area of ship structure remains measuring 43 m by 9 m (Cumming and Carter 1990:32; Petts 2003). Due to the cargo being the aim of the project, limited, although detailed, measurements of the timber hull were recorded and presented. Furthermore, a scaled drawing of the remaining hull structure provides additional context that complements the descriptive text.

Due to the large quantities of data and research (1,560 files and over 1,000 illustrations) the decision was made to publish it using a CD-ROM (Petts 2003). Ed

Cummings (2002) systematically designed an electronic document able to be viewed in a web viewer format. This provided a more accessible document while still maintaining all relevant information. The CD-ROM was accessed for this research at the British Library and is the primary source of information relating to the scantlings of *Earl of Abergavenny*. This vessel provides archaeological evidence of construction technologies relating to late-eighteenth century British East Indiamen.

3.6.7 *Java* (built 1811)

The ship, *Java*, was constructed in 1811 at the Blackmore and Company Yard in Howrah, Calcutta (Barnett 1991:9). The ship measured 159 feet 2 inches (48.5 m) in length, by 40 ft 6 inches (12.3 m) in width and had a tonnage of 1,175 tons. According to Stephen Barnett (1991:9), it was constructed in the style of an East Indiaman. In 1813, it was given a British registration and served the British East India Company until 1827 (Barnett 1991:9). Following 1834, the vessel owned by Mr Joseph Somes continued to be chartered by the British Government (Barnett 1991:11–12). The ship sailed globally calling into ports in North America, the West Indies, South Africa, Australia and Aotearoa New Zealand (Barnett 1991:12). In 1865, the vessel's sailing career was over and the ship became a coal hulk in Gibraltar (Lalvani 2016:65; Lubbock 1950:87). Unfortunately, the ship's working life was brought to a close when it was towed from its mooring in Gibraltar to be broken up in 1939 (Figure 12) (Barnett 1991:62). At the time, it was the last surviving early-nineteenth century British East Indiaman afloat (Peters 2013:19).

While not an archaeological site, a description of the hull can be used to understand the construction of an early nineteenth-century ship. William. H. Coates (1900) described *Java* according his observations of its exposed interior structure, i.e., not covered in coal. Additionally, Coates's observations are synthesised in Barnett's (1991:60–63) book, *Java*. These descriptions complement the historical and archaeological data from HMS *Buffalo*—a ship constructed around the same time and in the same area—and provide additional insights into the construction of the vessels of this period.

Figure 12. *Java* in Genoa for breaking up (1939) (https://gibraltar-intro.blogspot.com/2015/01/1811-java-triumph-of-skill-w.html).

3.6.8 *Diana* (built 1812)

Launched in 1812 in Chittagong and constructed using local timber, including Jarool[5], *Diana* was used in the country trade routes between China and India (Ball 1995:59, 121). This ship's construction is described as flush decked measuring 98 ft 4 inch (30 m) in length by 26 ft (7.9 m) in width and drawing only 15–16 ft (4.5–4.8 m) of water when fully laden (Ball 1995:52). On a return voyage from Canton, the ship sunk in 1817 in the Malacca Strait while enroute to deliver a shipment of porcelain to the BEIC in Madras (Ball 1995:59, 67). Divers formerly identified the wreck site in 1994 and began their recovery of its cargo (Ball 1995:121). The controversial project by today's ethical standards was entirely driven by salvage of the cargo under the guise of archaeology. Divers noted that 99 per cent of the hull had been consumed by *Teredo navalis* (shipworm) with the largest surviving timber measuring 2 m by 18 cm square. Furthermore, no ships plans exist for *Diana* (Ball 1995:52). Thus, *Diana,* is not directly used for this study, as the lack of hull remains makes it impossible to include with other archaeological data. Dorian Ball (1995:52–

[5] Jarul [Jarool], *Lagerstraemia regina* is a timber found in India.

57), however, provided a relatively detailed account of colonial shipbuilding in Britain and these published descriptions are used to discuss shipbuilding practices.

3.6.9 *Jhelum* (built 1849)

Jhelum, built in Liverpool in 1849, had its first registered dimensions recorded as 118.5 ft (36.11 m) in length, 24.6 ft (7.49 m) in breadth, 17 ft (5.18 m) depth of hold and 428.35 gross tons, and the ship is described as a 'well-built latest edition of a well-proven design' seen in British shipbuilding (Stammers and Kearon 1992:11–12). The vessel was eventually sold in 1874 and converted into a warehouse store and then into a hulk in Stanley Harbour, Falkland Islands (Stammers and Kearon 1992:38–47). Between 1987 and 1990, researchers from the Merseyside Maritime Museum, Liverpool, in collaboration with the Falkland Islands Museum and National Trust, produced an accurate plan of the remaining hull structure and recorded its construction features (Stammers and Kearon 1992:51–52). During this survey the bow was reported as in poor condition and by the early 2000s the ship remained in a deteriorated state (Figure 13). In 2013, long-term damage caused by teredo worm and gribble caused the hull structure to collapse in on itself and it continues to break down (Figure 14) (Alison Barton pers. comm. 2016).

Figure 13. *Jhelum*'s condition in 2006, Stanley Harbour, Falkland Islands (Courtesy of the Falkland Islands Museum and National Trust).

Figure 14. *Jhelum*'s condition when visited in 2016, showing only the aft section (Photograph: Nick Keenleyside).

Debate as to whether *Jhelum* was a derivative of the earlier East Indiaman design or a 'product of her time', culminated in the early 1990s (Bound 1990; Stammers and Kearon 1991). Michael Stammers and John Kearon (1992:13) argued *Jhelum* is more like a 'West Indiaman' and 'Guineamen' than an East Indiaman. Therefore, *Jhelum* provides examples of certain construction technologies that contribute to insights into early-nineteenth-century British domestic shipbuilding techniques.

3.7 Primary case studies

The following sets out the historical backgrounds, significance and previous investigations and site formation processes relating to *Endeavour*, HMS *Buffalo* and *Edwin Fox*. An extensive review of current literature describes these ships from construction to their wrecking or long-term preservation. The ships are nationally and internationally significant for maritime heritage and wider nautical archaeological studies. Finally, it is important to understand post-depositional site formation processes. Evidence from past histories suggest each of the three primary case studies' timber hulls have been modified over time. By examining site formation processes it enhances the researcher's understanding of the ship and its contents (Adams 2013:10). By doing so, we can determine what remaining structure there is available to study and to identify any modern salvage activity which might impact on detailed recording of individual timbers or materials.

3.7.1 *Endeavour* (ex *Lord North*) (built 1771)

3.7.1.1 Historical background

Constructed in 1771, in the Howland Dock, London, by John Wells, *Lord North* measured 138 ft (42.06 m) in length by 36 ft (10.97 m) in breadth (Figure 15). The vessel sailed four return voyages between 1771 and 1780 for the Company (Sutton 2000:151). After the Company's service, *Lord North* was continuously registered in the *Lloyd's Register of Shipping* until 1795 (Anon. 1795:L:264; Boocock and Kenderdine 1992:2). The vessel's last voyage from Sydney is well documented and is intertwined with other early European landings in Aotearoa New Zealand.

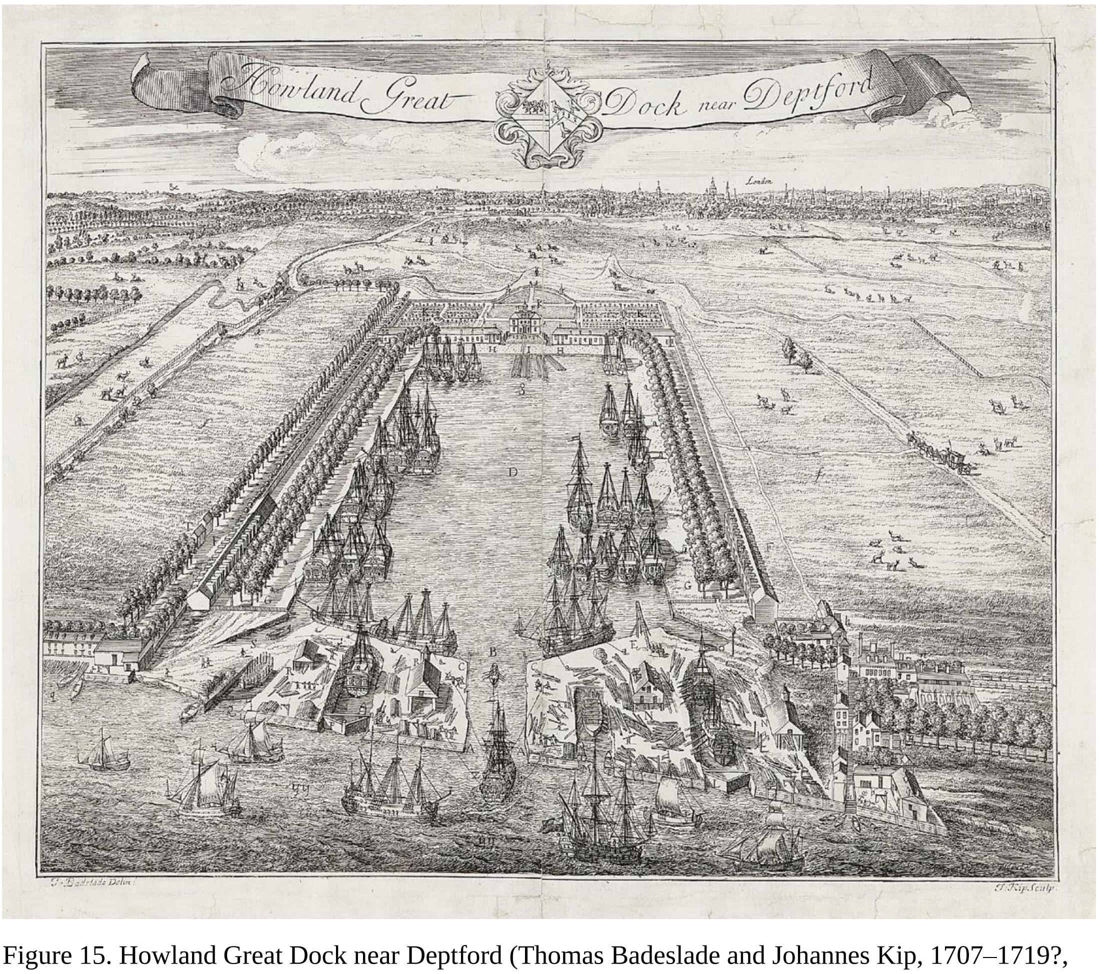

Figure 15. Howland Great Dock near Deptford (Thomas Badeslade and Johannes Kip, 1707–1719?, PAH1988, National Maritime Museum, Greenwich).

Prior to *Endeavour*'s abandonment, a sealing party was left in Tamatea Dusky Sound (see Figure 1) by Captain W. Raven of the ship *Britannia* in 1792 while on the way to the Cape of Good Hope (Ingram et al. 2007:9). The sealers were instructed to collect seal skins and wait for the return of their ship. As a precaution, in the event *Britannia* failed to return, 12 months of food, iron work, cordage, sails and other items for building a small vessel were left (Watson 1920:100). Eleven months then passed before the sealing gang was picked up by *Britannia* (September 1793) and returned to Sydney. During their time in Tamatea Dusky Sound, however, the sealers built a house and a wharf. With growing concern that *Britannia* would not return, the sealers began to construct a small ship. By the time the sealers were picked up, the ship under construction was estimated to be between 60 to 70 tons. It was described as 'a smart little craft, 53 feet long, had been built of local timber and was nearly ready for launching' (Watson 1920:100). It is possible this was the first European ship to have been constructed in Aotearoa New Zealand and the first in Australasia using native timbers (Ingram et al. 2007:9).

Endeavour, under the command of Captain William Bampton, sailed to Sydney from Surat/Bombay 17 March 1795 with 132 cattle and arrived on 31 May 1795 (Duggan 1997:107; Ingram et al. 2007:9). *Endeavour* then departed Sydney with the brig *Fancy* on 19 September 1795 for India (Ingram et al. 2007:9). As it happened, Mr R. Murry, fourth officer on *Endeavour* had also been onboard Captain Raven's *Britannia* in 1792 and it was Raven and Murry who informed Captain Bampton of the nearly finished vessel in Tamatea Dusky Sound (Duggan 1997:29). The planned voyage to India was to go via Aotearoa New Zealand to take 'ownership' of the ship left by the sealers. As *Endeavour* left Sydney and sailed across the Tasman Sea in bad weather, the ship began to leak (Ingram et al. 2007:9).

Robert Murry (1914:522) described:

> Saturday 3rd Octr.
> …In the morning it blew excessive hard, we were employed all hands at the pumps, the ship having made much water by working…

> Sunday 4th
> The pumps going constantly the whole 24 hours…
>
> Monday the fifth.
> …The ship still continuing to work very much,—always one, at times, two pumps going.

The pumps were worked continuously for three days before Bampton sailed *Endeavour* into Facile Harbour, Tamatea Dusky Sound sometime between 5 October and 12 October 1795[6]. Upon arrival, Captain Bampton found an enclosed shed measuring 40 feet long and a 'well built little schooner' (Watson 1916:230). Some planks had shrunk and cracked but overall, the ship appeared to be sound and well-seasoned (Ingram et al. 2007:9).

Endeavour was not considered a complete loss when first arriving in Tamatea Dusky Sound and sat moored in Facile Harbour. A survey of the ship on 20 October 1795, concluded:

> The condition we found her in, justifies what has before been said, from ocular demonstration we found, that, all the breast hooks were loose, they were on the spot prized very easily up with a crow. Of the lower one the bolts had worked 2 inches out. Her stern was entirely decayed and the remaining parts, as timbers, plank & lining in so bad a condition that we think it a miracle she [it] held together in the bad weather we experienced (Murry 1914:524).

On 27 October the ship struck a rock and settled in the bay (Ingram et al. 2007:10). On 1 November the ship was hauled up as high as it would go with the spring tide to assess damage and consider possible repair (Figure 16) (Murry 1914:527). It is not known if the ship underwent repair works but it was subsequently abandoned.

[6] Murry's journal is missing entries for these days.

Figure 16. An artist impression by Gainor Jackson of *Endeavour* hauled in close to shore (Courtesy of Toitū Otago Settlers Museum).

The ship left on the stocks by the sealers was finished off and named *Providence*. The newly christened vessel was filled with as many passengers as it could carry and sailed to Norfolk Island. A second rescue vessel was completed under the guidance of James [Hatherleigh] Hatherly[7]. *Endeavour*'s long boat was 'built into a very handy little vessel' and named *Assistance* (Watson 1916:230). Carrying crew and some cargo, it arrived in Sydney March 1796 and was sold for £250 (Ingram et al. 2007:11; Watson 1916:230). The last remaining passengers of *Endeavour* were rescued by the American whaler *Mercury* in May 1797 (Ingram et al. 2007:11; Watson 1916:230).

3.7.1.2 Significance and previous investigations

Endeavour is the first recorded loss of a European vessel in Aotearoa New Zealand (Ingram et al. 2007:9). It was abandoned in Facile Harbour, Tamatea Dusky Sound, alongside other equally important historical sites—being the location of the first European settlement and shipbuilding site in Aotearoa New Zealand (Hawkins 1978:1; Ingram et al. 2007:9; Locker-Lampson and Francis 1979:35). This significant area underwent an archaeological investigation in 1998 as part of the

[7] James Hatherly was previously a carpenter's mate on HMS *Sirius* (Watson 1916:230).

wider Dusky Sound Historical Project (Smith and Gillies 1997) and was conducted by Ian Smith with the Anthropology Department, University of Otago and Karl Gillies from the Southland Museum and Art Gallery Niho o te Taniwha (Smith and Gillies 1998). The fieldwork objective was to locate and investigate archaeological sites associated with *Endeavour*'s abandonment (Smith and Gillies 1998:1). While the project focussed on the terrestrial sites, 'no attempt was made to undertake detailed investigation of the *Endeavour* hulk' (Smith and Gillies 1998:17).

In the late 1970s, a request for a diver to photographically record the wreck was submitted to the Park's Board. According to Rachael Egerton's (n.d.) *Endeavour Salvage History*, John Campbell, a lecturer in the Physics Department of the University of Canterbury, visited the site over a period of 12 to 15 years and may still have photographs and additional information. Campbell was contacted by the author requesting access to these photos which would provide evidence of site condition in the 1970s. Campbell replied 'Well, that's me, but I have never dived on the *Endeavour* site nor been to it' (John Campbell pers. comm. 2020). Had the photographic survey been completed this would have been the first extensive photographic site condition record of the site.

The final voyage of *Endeavour* from Sydney and its abandonment in Tamatea Dusky Sound, is well documented in the diary kept by fourth officer, Robert Murry and is summarised in Sarah Ell and Gordon Ell's (1994) *Adventurous Times in Old New Zealand: First-hand Accounts of the Lawless Days*. The vessel's history prior to abandonment and specifically its construction history, is less well-known in current literature with publications focussing on post abandonment events. Publication about the ship has, to date, presented inconsistent details regarding the vessel's construction date and dimensions, and has confused this ship with others of the same name. The first mention of questionable measurements was reported by Captain John Fairchild, of the New Zealand Government, Marine Board, Steamer, *Hinemoa*, who visited the ship site in 1878:

> She [*Endeavour*] is in a little nook, or pocket, so small that it was impossible for her to sail in. She [It] must have been hauled in with ropes made fast to trees. She [It] is 180 feet long and about 43 feet in beam. … She [it] is a good model and I think, was a fast sailer, and she

> [it] must have been between 700 and 800 tons register (Hocken 1888:423–424; Hughes 2014:611).

The dimensions estimated by Fairchild appear to be larger than what would be common for a late-eighteenth century East Indiaman. However, Robert McNab's (1907:68) book *Murihiku and the Southern Islands* stated that after Captain Fairchild again visited the site in 1895, he later revised the ships length down to 128 feet (39 m) keel from 180 feet (54.8 m) (Ingram et al. 2007:11). It was later determined that Fairchild changed the size of the vessel to fit his personal belief that the hull remains were that of the ship of the same name that lieutenant James Cook[8] commanded between 1768 and 1771 (McNab 1907:68). A belief refuted in several later texts (see Boyle et al. 2006:134; Ingram et al. 2007:11; McNab 1907:68). However, in the 1970s, a New Zealand wreck book published the overall length at 180 feet (54.8 m) and a beam of 32 feet (9.7 m) which appears similar to Fairchild's original estimates (Locker-Lampson and Francis 1979:35). Recently, archaeological investigations have attempted to relocate Cook's *Endeavour* (renamed *Lord Sandwich*) in Newport Harbour, USA (Hunter 2020; Hunter et al. 2018). Therefore, the shipwreck of *Endeavour* in Tamatea Dusky Sound is not the same vessel as commanded by James Cook.

Another conflicting detail is the question over the vessel's construction date. In Steve Locker-Lampson and Ian Francis' (1979:35) book *Rediscovered New Zealand Shipwrecks: The Wreck Book*, it stated the ship was 'built in about 1724' with no reference. Later, in 1992, Angela Boocock and Sarah Kenderdine (1992) produced *The Endeavour: An Historical Account of New Zealand's Earliest Recorded European Shipwreck, and Research Potential of the Archaeological Remains of the Vessel*. Under the heading 'construction details', they specify *Endeavour* was constructed c.1724/1725 and measured at a length of 180 feet (54.8 m) by 32 feet (9.7 m) breadth (Boocock and Kenderdine 1992:2). Interestingly, the authors point out 'considering an average age of vessels of 16 or 17 years at this time, the *Endeavour* was in service for an extremely long time, being 74 years old when

[8] James Cook never held rank of captain. During the first voyage (1768–1771), Cook held the rank of lieutenant. Upon returning to Britain in 1771, he was promoted to the rank of commander. Later in 1775, he was promoted to the higher rank of post-captain (see https://www.captaincooksociety.com/home/captain-cook-society/faq).

wrecked' (Boocock and Kenderdine 1992:2). Thus, *Endeavour*'s construction date considered to be in the 1720s is improbable and would place the original construction date either in the 1770s or 1780s. Furthermore, the dimensions have remained fairly consistent over time, however, due to other inaccuracies the original measurements are considered unreliable. It is also noted that the ratio of length to breadth is approximately 6:1 'making this vessel very long compared to its width', when in reality the ratio should be closer to 3:1 (Boocock and Kenderdine 1992:2).

A valuable piece of information that appears in literature is the identification of *Endeavour* being formerly known as *Lord North* (Boocock and Kenderdine 1992:2; Cotton 2010:Part 2-230; Duggan 1997:103). However, existing published facts surrounding the launching, naming, origin and dimensions of *Endeavour* are approached with caution for this study. Therefore, this investigation, using archival research traces the history of the vessel to determine its original construction date and original measurements. This is necessary to confirm if the vessel is *Endeavour* and a British East Indiaman.

3.7.1.3 Site formation

As equally interesting as *Endeavour*'s active sailing history, is its modern history. Here, post-depositional activity is highlighted providing evidence of loss of vessel structure. This short review also provides context to salvaged remains that are now in museum collections, such as the *Endeavour* timber collection at the Southland Museum and Art Gallery Niho o te Taniwha used for this study.

Shortly after the abandonment of *Endeavour* sealers and whalers salvaged sections of the vessel, including metal and timber components (Egerton n.d.). In addition, early opportunistic salvors visited the ship site. For example, George Bass (for whom Bass Strait in Australia is named), visited the site around 1802. In a letter written to a Captain Waterhouse on 5 January 1803, Bass wrote (Ingram 1977: 2):

> I shall go to Dusky Bay again this voyage for the purpose of picking up two anchors and breaking the iron fastenings of an old Indiaman that lies derelict there…, now we shall be prepared for breaking her up.

Bass indicated he will sail on *Venus* '…to pick up something more from the wreck of the old *Endeavour* in Dusky Bay' (Ingram 1936:2). In 1878, Captain Fairchild visited the site and he observed that the vessel had been hauled up on the beach using ropes (Egerton n.d.). He also reported that sealers had cut the timbers down to the water's edge to use as firewood (Figure 17) (Egerton n.d.).

Figure 17. *Endeavour* marked with a leaning stake lodged in the ballast pile, when visited by Richard Henry between 1894–1900 (The University of Otago Library, The Hocken Collections / Uare Taoka o Hākena, Richard Henry Collection, 9029).

The 1960s, 1970s and 1980s saw increased salvage activity where small and large sections of the ship's structure were removed (Egerton n.d.). The area was being visited more by tourists, divers and fishermen (Egerton n.d.). In the early 1970s, Fiordland National Park Board notified the Marine Department of skin divers removing relics from shipwrecks in the Sounds (Egerton n.d.). In response to this (over the next five years), the Parks Board operated on a policy of removing artefacts before anyone else could (Egerton n.d.). Meanwhile, private salvage was continuing. In June 1974, Kevin Ritchie on the vessel *Bert Moss* removed a wood fragment and, after investigation, he returned the timber (Egerton n.d.). Also, in 1974, a section of teak was collected by John Ward and held at Deep Cove (Egerton n.d.). At the same time, public awareness about the site was being created by the Historic Places Trust with a possible visit to survey the site (Egerton n.d.). As a result, this increase in publicity drew more souvenir hunters to the location of the shipwreck (Egerton n.d.).

During the 1980s, there was increasingly widespread concern for the condition of *Endeavour* (Egerton n.d.). The Lyttelton Historical Museum Society wrote to the Park Board stating they thought most of the timbers had disappeared and the ballast pile had been moved to allow fossickers access to the hidden structure (Egerton n.d.). The Southland Museum became interested around the same time and made inquiries about the wreck to the Parks Board (Egerton n.d.). Chief Ranger W.E. Sander replied:

> To put you in the picture re the wreck, over the time that I have been keeping an eye on it, i.e since 1972, when I first viewed the site in winter of 1972 there was a considerable amount of timber in evidence with a section of keel being the most obvious together with the ballast. I did not dive on the site at that time and what I saw was viewed from the surface. In September 1974 I viewed the wreck again. This time I dived on the site and the only obvious change was that the exposed section of the keel had been removed, the rest being much as I had seen it two years before. After making inquiries I learned that the missing section of keel had been towed away.

He continued, ‘in December, 1974, I found at least some of the missing section where it had been towed…and on inspection found that the copper fastenings had been either removed or sawn off’. The ranger recovered the timber and it is likely this is part of the Southland Museum and Art Gallery’s collection used for this study.

He noted, that since 1974, after regular monitoring, there was a steady disappearance of timbers (Egerton n.d.). Furthermore, site disturbance action included removal of ballast stones and sawing off the exposed copper fastenings. A person by the name of Tarrant was mentioned as planning to use explosives to remove material but was talked out of it at the last minute (Egerton n.d.).

On 9 December 1980, divers exploring the site noted that planks were scattered around the wreck and some still had copper sheathing attached in a deteriorated condition (Boraman 1980). An expedition in 1984, led by Simon Cotton, recovered *Endeavour*’s cannon from Facile Harbour and at the same time photographed evidence of salvage activity, non-ferrous fasteners and hull timbers at the shipwreck site (Figures 18–20) (Cotton 2010:Part 2-250–Part 2-259; Sale 1988:197–199). Roger Grace, a member of the same expedition team, described seeing ‘several heavy cuprous nails had been vandalised, their shining surface indicating a recent cut’ (Cotton 2010:Part 2-254). No systematic survey of the wreck site was completed as the visit prioritised relocating and retrieving the cannon. In a 1985 visit to the site, Rick McGovern-Wilson and Jack Fry noticed signs of fossicking with a section of plank on the foreshore (Egerton n.d.). McGovern-Wilson later commented on how important it was that a management strategy be developed for historic sites within the park (Egerton n.d.).

This review of *Endeavour*’s post-depositional salvage history illustrates that the shipwreck site has been heavily modified over time. Additionally, the salvaged timbers currently housed in museum collections are likely to have come from the wreck site. This understanding allows for this research to examine the timbers in museum collections knowing they were once part of the ship. However, due to the past limited capabilities in site recording, survey and policing, timbers held in museums must be approached with some level of caution as to their original context and provenance. This study attempts to provenance the timbers to understand the timbers’ individual contextual information.

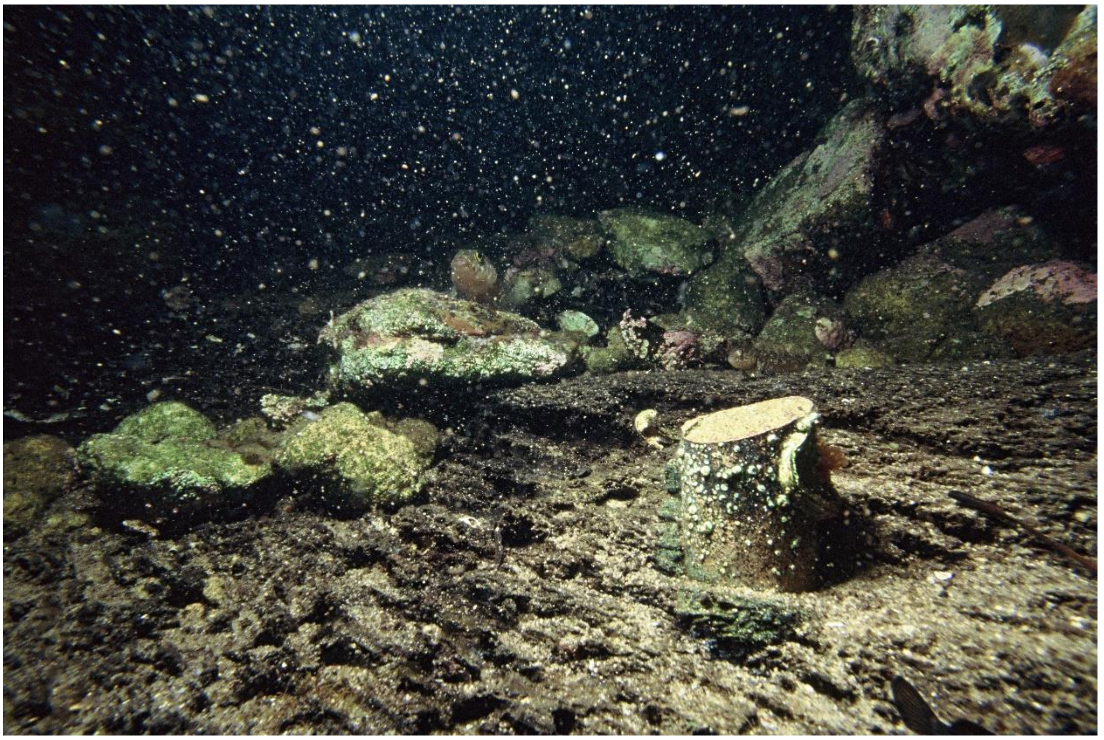

Figure 18. Evidence of salvage with a cut non-ferrous fastener on the *Endeavour* wreck site photographed 6 March 1984 (Photograph: Roger Grace, courtesy of Phyllida Cotton-Barker).

Figure 19. A non-ferrous fastener in *Endeavour*'s ship timbers photographed 6 March 1984 (Photograph: Roger Grace, courtesy of Phyllida Cotton-Barker).

Figure 20. Diver with *Endeavour* ship timbers photographed 6 March 1984 (Photograph: Roger Grace, courtesy of Phyllida Cotton-Barker).

3.7.2 HMS *Buffalo* (ex *Hindostan*) (built 1813)

3.7.2.1 Historical background

Shipwrights constructed *Hindostan* in the Bonner and Horsburgh shipyard, Sulkea, India and it was launched 4 January 1813. When completed, the vessel measured 120 ft (36.6 m) in length, 33 ft 10 inches (10.31 m) in beam by 15 ft 8 inches (4.77 m) in hold depth and was registered at 589 tons (Ingram et al. 2007:28; Riddle and Bithell 2015:3). In November 1813, the British Admiralty purchased the ship and used it as a storeship in the Napoleonic Wars (Riddle and Bithell 2015:3). During this service the vessel was renamed HMS *Buffalo*. After the ship's service in the war, it visited ports in Bermuda, Halifax (Nova Scotia), Barbados, Antigua, Jamaica, Malta and Gibraltar (Riddle and Bithell 2015:4). Then between 1819 and 1830 the vessel's sailing records are infrequent. It is not until 14 June 1830 that the Navy Board advised the Admiralty that the ship would be repurposed as a quarantine ship at Stangate Creek, Sheerness (Bennett 2020; Riddle and Bithell 2015:4). The ship provided a quarantine space to air out incoming goods before their distribution among the general population (Riddle and Bithell 2015:4).

In 1833, the Admiralty recommissioned the ship to continue the British colonial expansion into Australia and Aotearoa New Zealand. The ship's accommodation was reconfigured to transport women convicts to New South Wales. Then on the return journey, HMS *Buffalo* sailed via Aotearoa New Zealand to pick up a load of timber masts and spars. The ship is noted to have carried a suggested national flag design for Aotearoa New Zealand, but this was later rejected by James Busby in favour for the 'United Tribes of New Zealand' flag (Riddle and Bithell 2015:5).

The ships next commissioning happened in 1836 and the hull was refitted to provide accommodation for 200 emigrants (Figure 21). This time the ship sailed from Britain to what was to be declared the province of South Australia on existing Aboriginal Country. Proclamation of the new state happened on 28 December 1836 and Captain John Hindmarsh of HMS *Buffalo* became the first Governor of colonial South Australia. On 10 September 1837, the ship departed South Australia to Britain, sailing via Aotearoa New Zealand to pick up more timber spars and to survey

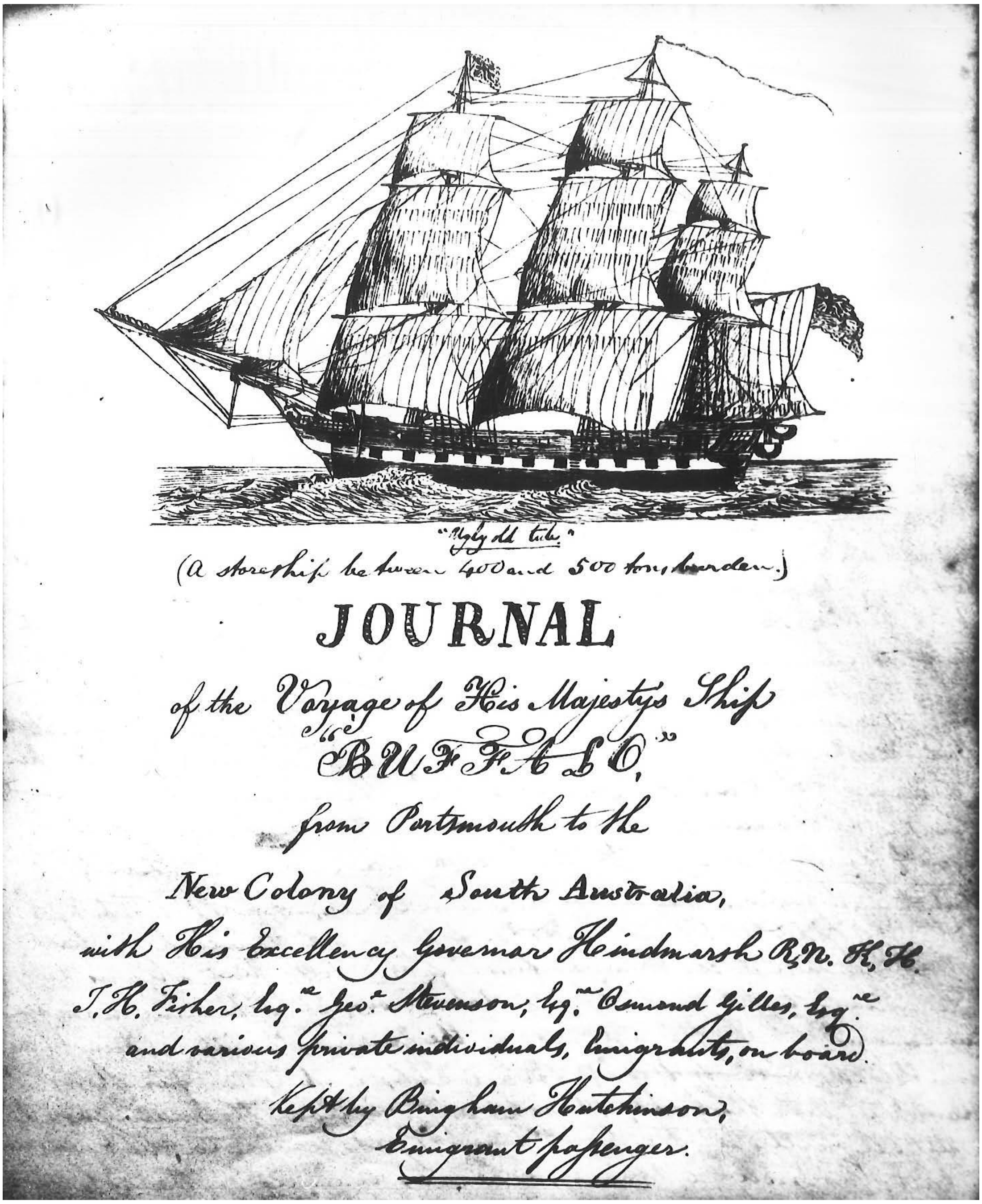

Figure 21. A depiction of HMS *Buffalo* in 1836 by Young Bingham Hutchinson, Borrow Collection, Flinders University.

some of the coastline (Riddle and Bithell 2015:8). In the following years, the ship was then reconfigured for transporting troops to Canada and subsequently, convicts to Australia. It was not until 3 April 1840 that HMS *Buffalo* sailed from Sydney to Aotearoa New Zealand to pick up more timber, this time carrying Major Thomas Bunbury, crown troops and other passengers. Bunbury would later travel around

Aotearoa New Zealand in HMS *Herald* collecting signatures for Te Tiriti o Waitangi[9].

On 28 July 1840, while anchored in Cooks Bay, east of Whitianga, HMS *Buffalo* was caught in a storm and dragged its anchor (Figure 22). The ship subsequently lost its anchors, rudder and ultimately the captain relinquished all control. Eventually, the ship was driven on shore and wrecked with the loss of two crew.

Figure 22. 'The storm', HMS *Buffalo* 1840 (Paul Deacon).

3.7.2.2 Significance and previous investigations

The ship HMS *Buffalo* is of global interest. The vessel's history connects several countries, including its construction in India and transporting people and cargo between the island nations of Britain, Australia and Aotearoa New Zealand. Specifically, HMS *Buffalo* was one of the first four ships to transport immigrants to the colony of South Australia and it's first governor, Captain Hindmarsh. This connection with South Australia sparked interest from the State Heritage Branch, the Department of Environment and Planning, to investigate the shipwreck remains of HMS *Buffalo,* the timing of which coincided with South Australia's 150th jubilee celebrations (Jeffery 1988:43).

[9] Te Tiriti o Waitangi was the Māori version of the Treaty of Waitangi signed by Māori chiefs with the main ceremony taking place at Waitangi, 6 February 1840.

In 1986, a team of five divers, led by Bill Jeffery from the Department and volunteers from the Nautical Archaeological Association of South Australia (NAASA), visited the shipwreck site in Mercury Bay, Whitianga (Jeffery 1988:43). The purpose of the project was to survey, map and excavate part of the wreck site. Before excavation could start, the team needed to locate and identify the shipwreck. After completing a magnetometer survey in an area which measured 50 m by 75 m, a 36 m long anomaly appeared in an east-west orientation by 10 m in width in a north south orientation. The anomaly was inspected and the shipwreck site was found to measure 36 m (118 ft) long and 10 m (33 ft 10 in.) wide (Jeffery 1988:43). The identification was also checked against existing literature such as Robert Sexton's book *HMS Buffalo* (1984), photographs of the shipwreck site taken during the 1960s earthquake/tsunami, and by verifying the location using local knowledge from people who had dived on the site.

A general inspection in 1984, reported 'large sections of the site were found to be uncovered, including a considerable portion of the iron ballast' (Jeffery 1988:43). Other exposed material was noted as several wooden frames extending 50 cm in height from the seafloor. Based on this visible extent and the site condition, it was decided by the team to excavate a trench in a north south orientation, seven metres from the shore end of the shipwreck (Jeffery 1988:43). The trench was constructed using four 2 m by 2 m plastic squares with each individual square being excavated before progressing to the next square. After this trench was completed, a second trench was placed 28 metres from the shore end and consisted of three squares. Two squares were excavated across the ship site and the third square was continued longitudinally (Jeffery 1988:43). After recording each trench, they were both backfilled with surrounding sand.

The results of the survey recorded ship's hull structure, copper sheathing fragments, personal items and large concretions. The remaining hull structure was said to be in very good condition noting the keelson running the full length of the site, ceiling planking, frames, outer planking and iron, brick and rock ballast.

The recorded archaeological data was sought during this research with the intention to incorporate timber dimensions into this study. In a letter addressed to Bill Jeffery, The Mercury Bay Museum secretary and historian, J.I. Riddle (2001) asked the question ‘was a more detailed [archaeological] report done, or was it shelved?’ A report would have aided in providing detailed measurements of the shipwreck timbers. However, no detailed report was ever completed (Bill Jeffery pers. comm. 2017). As a result, there are no further detailed measurements available for this study.

Today, the shipwreck is a protected archaeological site under the *Heritage New Zealand Pouhere Taonga Act 2014*. The site is still accessible to the public for snorkelling and diving and is marked with a buoy for easy relocation. The nearby Mercury Bay Museum holds a collection of material that has been salvaged or washed ashore from HMS *Buffalo*.

3.7.2.3 Site formation

In the months immediately following the wrecking, the ship was stripped down and its cargoes removed. The masts were stripped of their rigging, a hole cut into the starboard side to access the spirit room, the decking over the magazine was lifted and the forecastle deck and bowsprit were removed (Riddle and Bithell 2015:15). Notably, planking was reused to build a deck on the barque *Bolina* and the same ship carried away what remained of the masts for firewood (Riddle and Bithell 2015:15).

Over time, the ship continued to be stripped down for materials. In the late 1890s, Henry Sparks, Mayor of Glenelg, South Australia, financed the salvage of 40 tons of timber and had the usable wood fashioned into the Mayoral chair which he gifted to the town in 1899 (Anon. 1937; Garnaut et al. 2016:7). The chair is on display in the Bay Discovery Centre, Glenelg. By the 1920s, the timber hull had been increasingly cut down and with tidal action became submerged (Riddle and Bithell 2015:16). This, however, did not deter souveniring. On 2 February 1936, a ‘teak stem’ with metal sheathing was likely recovered from the bow and kept in private ownership for some time (Figure 23). The present location of the timber and attached sheathing is unknown.

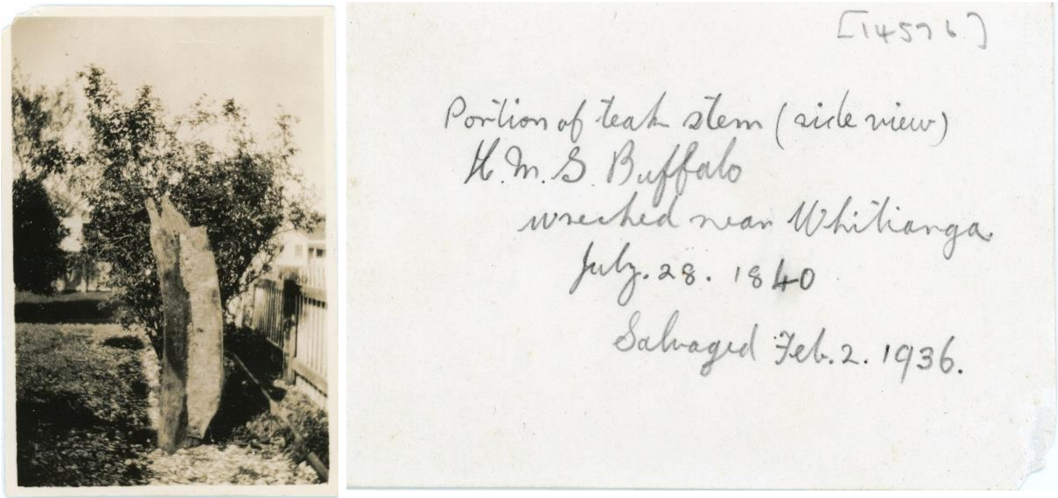

Figure 23. HMS *Buffalo* stem (left), description written on back of photograph (right): 'Portion of teak stem (side view), HMS *Buffalo*, wrecked near Whitianga, July 28 1840, salvaged Feb 2 1936'. (New Zealand Maritime Museum Hui Te Ananui a Tangaroa, 2003.14.2).

In 1960, earthquakes that occurred off the coast of Chile, South America, caused a tidal surge which exposed the *Buffalo* shipwreck (Ingram et al. 2007:28). A newspaper article, described the reaction to the exposed shipwreck as 'residents rushed to the wreck…They searched for relics in spite of the likelihood of the tide's flowing quickly' (Anon. 1960). The public managed to collect pieces of teak and copper from the keel during a 20-minute window 'before a crowd on the shore bank shouted to those at the wreck' warning them of the incoming tide (Anon. 1960).

Over time, ship timbers reappear in the sand along Buffalo Beach. Most recently, in April 2019, a 3 metre long plank with evidence of metal sheathing was spotted sticking out of the sand by the public (Anon. 2019). The plank was delivered to the museum and is included in this study. There is a high probability that more ship components remain buried in the beach and will become exposed through future natural erosion processes.

3.7.3 *Edwin Fox* (built 1853)

3.7.3.1 Historical background

In October 1853, a team of British and Indian shipwrights completed the construction of *Edwin Fox* in the Reeves and Foster shipyard, Salkea (Salkia), India (Bennett 2018:82). It is thought the British East India Company originally commissioned the construction of *Edwin Fox*, in a shipyard in Bengal, India;

however, the ship's registration certificate lists Thomas Reeves as the sole owner (Costley 2014; Schauffelen 2005).

> *Edwin Fox*…was built at Sulkea in the Province of Bengal in the present year 1853 for and on account of the said Thomas Reeves under the superintendence of the said William Henry Foster as appears under his hand dated 6.12.1853 and Joseph Simpson, Marine Surveyor and builder in the service of the Honourable East India Company (Bowring 1853).

On 9 December 1853, the completed vessel was issued with certificate number 12/1853 and registered at 835 tons, measuring 157 feet (47.85 m) in length (LOA), 29 ft (9 m) in breadth and 21 feet 6 inches (6.55 m) deep (Costley 2014:33). The hull is constructed of teak (*Tectona grandis*) and sal (*Shorea robusta*) timber and sheathed in Muntz (yellow) metal (Martin and Davey 1854; Mortiboy et al. 2003a). Originally, the ship was full-rigged, but was later changed to a barque rig in 1878 (Locker-Lampson and Francis 1979:30).

On its maiden voyage, arriving in London, the British Royal Navy contracted the ship and converted it into a troop carrier. In 1854, the vessel transported soldiers during the Crimean war and was stationed there as a floating barracks. After the ship's duties in the war effort, the interior of the ship was converted a second time to accommodate prisoners. During the late 1860s and early 1870s, the British government contracted the vessel to serve as a convict ship and transported prisoners to Western Australia. In 1873, the vessel continued to be used to transport people, however, the type of passenger changed. The ship's accommodation was upgraded for paying customers and transported immigrants between Britain and Aotearoa New Zealand until 1880 (Costley 2014:140; Locker-Lampson and Francis 1979:30–31). Shortly after the ship's final voyage transporting immigrants to Aotearoa New Zealand, the ship was converted into a refrigeration meat store and moored in ports around the country. It served as a store ship in Port Chalmers, Ōtepoti Dunedin, Ōhinehou Lyttelton, and Tūranga-nui-a-Kiwa Gisborne (Costley 2014:152–153). Towards the end of the vessel's working life, the rigging was cut down as it was no longer needed. *Edwin Fox*, c.1900, became a permanent feature in Waitohi Picton (Figure 24). The New Zealand Refrigeration Company converted the vessel into a storage ship storing frozen animal carcasses. Around the 1920s, the freezing equipment was moved from the ship and installed in the adjacent Refrigeration Company's factory. The ship then served as a coal hulk to fuel the freezer boiler systems (Locker-Lampson and Francis 1979:30–31).

Figure 24. *Edwin Fox* c.1900 (Ship Edwin Fox at Picton (Daroux, Louis John, 1870–1948: Photographs of New Zealand and the Pacific. Ref: 1/1-039355- G. Alexander Turnbull Library, Wellington, New Zealand. /records/23160152).

In 1965, the Maritime Transport Authority inspected the ship and assessed the vessel to be unseaworthy and recommended it be condemned. Local enthusiasts, however, identified the historical significance of the vessel and formed the Edwin Fox Society to save the ship. The society purchased *Edwin Fox* for one shilling ($1.96 NZD 2017) from the New Zealand Refrigeration Company and pursued restoration options. During the following 16 years, the Society and the Marlborough Council discussed where to display the ship. It was not until 1986, that the ship's hull gained statutory approval and was moved to its final position now along Picton's foreshore and adjacent to the Interislander Ferry terminal. During the same year, construction of the associated museum building started with the design replicating the historic offices from Dunbar Wharf, London (Costley 2014:186). The vessel was moored next to the museum and remained floating until 1999. On 19 May in the same year, construction of a purposely designed dry dock was completed and *Edwin Fox* became a static and dry display—finally ending its 146 years of marine service (Figure 25). The ship currently forms the main exhibit of the Edwin Fox Maritime Museum and provides interactive displays with access to view the internal and external hull structure.

Figure 25. The Edwin Fox Maritime Museum (centre) positioned along Waitohi Picton's foreshore (Photograph: Irene Vigiola Toña 2018).

3.7.3.2 Significance and previous investigations

In 1987 and 1988, the *Edwin Fox* hull underwent a comprehensive survey. Earthwatch International funded the project which invited volunteers to contribute to the survey and recording of the vessel (Costley 2014:182–184). The project's objectives were to measure and record the hull dimensions to produce ships lines and to accurately record all construction features. In addition, the recorded information about the vessel's dimensions and deteriorated areas enabled the team to propose a full restoration plan. The goal to restore the hull, however, has now been abandoned with preservation now the focus. Plans and drawings produced during the Earthwatch survey are stored at the Marlborough Museum Archives and provide a record of ship condition during the late 1980s. These archives were accessed for this study. In 1999, the New Zealand Historic Places Trust (after 2014, Heritage New

Zealand Pouhere Taonga), the government agency that manages historic places, registered the hull and its associated windlass as Category 1, registration number 7450. Category 1 status is awarded to places or objects with special or outstanding historical or cultural significance or value. Currently, *Edwin Fox* is the only surviving historic vessel located in Aotearoa New Zealand to be assigned Category 1 status, which further reflects its historical significance.

Internationally, the vessel's historical significance was recognised, and in 2013 the Edwin Fox Maritime Museum was awarded the World Ships Trust Award for preservation. This award acknowledges *Edwin Fox* as a vessel that had a significant role in the history of humanity and its presentation and display advances public education. Building on this recognition, this research further enhances existing museum displays through new interpretations of the ships' hull.

Costley's (2014) book, *Teak and Tide: The Ebbs and Eddies of the Edwin Fox*, documents the history of *Edwin Fox* in its commissions as a British colonial built merchant vessel. This book uses archival sources to produce a biographical account of the ship's life from the time it was constructed to when it was preserved as a museum artefact. Specific to changes in design and construction, the author discussed the reasons for the BEIC to establish shipbuilding yards in eastern India and the incorporation of Hindu naval architecture into British shipbuilding (Costley 2014:20–21). For example, in the eighteenth century, Gabriel Snodgrass, the Company's chief surveyor, was so impressed with the stability of the straight-sided Bengali ships that he advocated against the traditional East Indiaman tumblehome design (Costley 2014:21–22). This historical account provided context for future ship adaptation related studies. Furthermore, this observation poses the question, how were structural components of a ship modified to suit these new square-walled designs? This research will specifically consider these issues through new data.

3.7.3.3 Site formation

After the *Edwin Fox* Society secured the vessel from inevitable destruction in 1965, the vessel stayed bogged on a tidal flat in Shakespeare Bay, Picton (Figure 26) (Costley 2014:9). It was 21 years later, in 1986, that efforts were made to refloat the ship and to preserve it in a more suitable location (Costley 2014:9). Meanwhile, opportunistic salvors cut timbers and collected items from the hull (Costley 2014:10). In preparations for the float, the hull was inspected by a chance visit by Ian McLeod from the Western Australian Maritime Museum, and he inspected the hull. McLeod said, ‘the lines look true’ and believed the vessel would float (Costley 2014). This suggests the condition of the hull was still rigid and, to a degree, intact enough for it to float again. Believing it could be refloated, holes were covered with additional plywood and polythene sheets and the antifoul (metal sheathing) was scraped of marine growth (Costley 2014:14). After months of work, the ship floated and was towed to a new location on 4 November 1986 (Costley 2014:14). In recent years, no timbers have been actively removed unless deemed unsafe. New stanchions have been added to support existing deck beams and an interpretation area with replica cabins has been installed in the bow. This demonstrates that the existing materials available for recording are original with other timber structure missing through the combination of environmental and cultural processes over time (Figure 27).

Figure 26. The bow of *Edwin Fox*, prior to its refloating (Photograph: Ian McCleod c.1986).

Figure 27. *Edwin Fox* in dry dock at the Edwin Fox Maritime Museum, Waitohi Picton (2017).

3.8 Conclusion

This thesis investigates British East India Company ship design and construction during the period from the mid- to late-eighteenth century to the mid-nineteenth century. During this time, the Company was influencing design and construction conditions on its ships while experiencing increased demand for timber supplies. The Company's connection with the East opened new timber supply and with it new material from which to construct ships. Through mismanagement, however, Indian teak forests were decimated. *Endeavour*, HMS *Buffalo* and *Edwin Fox* present an opportunity to study ship remains that reflect this time period and influences exerted by the Company.

The three case studies chosen for this research presented the author with different hull materials for recording. These included an extant hull, disarticulated ship timbers and unprovenanced ship materials. This in turn employed different methodologies to extract the data required to answer the research question. Working with different types of hull remains, however, limited the data for comparison within this thesis. These limitations are later explored in the discussion chapter and again highlighted in the conclusion chapter.

Chapter 4. Methodological approaches

This study investigates British East India Company ship design elements and construction technologies and focusses on the case studies of two archaeological and one historically preserved ships. These included ship timbers recovered from *Endeavour*, the disarticulated timber remains of HMS *Buffalo* and the preserved *Edwin Fox* hull. This research applies a combination of methods to extract the data required for this investigation. These include archival research, ships' lines drawings, scaled timber feature drawings, laser scans, construction drawings, wood identification, dendrochronology, metal analysis, fibre identification, organic analysis and photography. The combination of these methods extracts the physical and written information for qualitative and semi-qualitative analysis required for this study.

This chapter presents the methods specific to the investigations of disarticulated timber hull remains and to preserved hull structures, because existing remains of each ship differ. *Endeavour* is investigated through archival research, hull reconstruction, timber fragment recording, wood identification, metal analysis, fibre identification and organic analysis. The HMS *Buffalo*'s ship timbers are recorded using timber fragment recording techniques, wood identification, metal and organic analyses. Due to the size and complexity of the *Edwin Fox* hull, methods for its recording include laser scanning and 3D digital modelling, manual baseline offset recording, wood identification, dendrochronology, metal analysis, fibre identification and organic analysis. A catalogue of the *Edwin Fox* timbers has been created to draw comparisons between each vessel and their construction components. Therefore, due to the different archaeological materials, each ship requires different recording methods to extract data to enhance our understanding about BEIC ship design elements and construction technologies.

4.1 Archival research

Current literature relating to *Endeavour's* construction date is inconsistent. Archival research was therefore required to determine the correct construction date. In addition, historical research was used to confirm the current literature's historical timeline of *Endeavour*. Historical documents relating to *Endeavour* were accessed by the researcher at public archive depositories in London, between June and July 2017. Archived materials were viewed at the British Library and the Caird Library at the National Maritime Museum, Greenwich. Specifically, libraries were visited to access the India Office Records and Private Papers, which include the Honourable East India Company records (1600–1858) and other maritime related archives. These collections were searched to determine dates relating to the vessel's construction and service history.

The researcher decided it was unnecessary to thoroughly search archival material relating to HMS *Buffalo* as significant research had already been completed by Sexton in 1984. The author also included the reproduction of ships plans held by the National Maritime Museum, Greenwich. The construction date for HMS *Buffalo* (ex *Hindostan*), however, was rechecked for consistency while at the British Library and Caird Library.

Although there has been previous extensive historic research and subsequent literature published about *Edwin Fox* (see Costley 2014), it was decided that while at the British Library in June 2017, that records relating to the vessel's construction, registration and voyages should be rechecked. Keywords relating to the ship, the shipwrights, location of construction and the shipyard were searched, and the relevant documents recorded using the scanning mobile app or photographed where permitted. Furthermore, marine records relating to *Edwin Fox*'s port of registry were requested at the National Archives, Kew, London. These registers helped to confirm the ship's specifications, including, construction date, registration number, tonnage, length and breadth.

The Marlborough Heritage Trust archives, located at the Marlborough Museum, Blenheim were visited on 19 April 2017 to access the plans and drawings of the

Edwin Fox hull drawn up by the Earthwatch Project in 1987 (Figure 28). This project recorded the ships lines and produced construction drawings of the hull as it existed in the 1980s. It was then intended by the Edwin Fox Society to use these drawings to produce a restoration plan for the ship, however, the planned restoration never eventuated. The drawings and plans from the Earthwatch project are used in this study to complement the hull data captured in 2017. This contributes to understanding the level of degradation of the hull over time and eliminating modern distortion of the structure when analysing the historic hull shape.

Figure 28. Katarina Jerbić and Kurt Bennett photographing the Earthwatch *Edwin Fox* drawings (2017).

Additional records were viewed at the New Zealand Maritime Museum Hui Te Ananui A Tangaroa. The museum’s library holds *Edwin Fox* Society newsletters dated between 1987 and 2006 in its collection. Specifically, this information is used to detail ongoing restoration efforts in order to determine if any major contemporary components or structure have been added. This is to rule out modern materials from this study. The museum also has in its possession a half model of *Edwin Fox*. Traditionally, a shipbuilder would create a half model of the planned ship for construction and then scale up from the model by taking the offsets along the hull.

This half model of *Edwin Fox*, however, is not original and has been shaped from the measurements of the extant hull in recent times.
Additionally, archival resources at the British Library were searched for information relating to the views expressed about suitable timbers for use in the shipbuilding industry, management of forests and timber resources for future use. The East India Company Records were checked during the same visit when researching *Endeavour* and *Edwin Fox*. Specifically, the following records were inspected, 'Sketch of the present state of oak timber in England, and the prospect of supply &c. (1796)', 'Forests of Malabar (1806)', 'A report on the state of the forests of Teak…(1808)', 'Ships timbers, abstract of evidence before House of Commons 1814', 'A view of the present state of the timber trade in the province of Malabar with a plan for its improvement and the increase of the Honorable Company's revenue (1835)' and 'Timber preservation (1846)'. Relevant information was either photographed or scanned and converted to a pdf file using the TinyScanner mobile app.

Information relating to the shipbuilding industries in Britain and India during the late-eighteenth and mid-nineteenth centuries was collected from archival materials. This information was collected during the same visit researching *Endeavour* and *Edwin Fox*. The Honourable East India Company records at the British Library were examined for descriptions relating to the shipbuilding process and personal accounts describing the attitudes towards the shipbuilding industry. Relevant records were photographed where permission allowed, otherwise notes were transcribed by hand. This research contributes to understanding the social and economic attitudes impacting shipbuilding which is an integral part of this study. Furthermore, archival research confirmed the original construction dates of the vessels and provided insights into shipbuilding practices at the time.

4.2 Ships lines

Ships lines for the three case studies were drawn to analyse hull design parameters. The *Endeavour* and *Buffalo* ships' lines were reproduced from historic plans while *Edwin Fox* was reproduced directly from the laser scan data. Existing plans and laser scan data provided the X, Y and Z axis data to be replicated in a text file and imported into a naval architecture program. DelftShip—a free downloadable software designed for naval architecture—required importing three sets of coordinates into the program to digitally reconstruct the hull shape and to produce the ships lines. The offsets were rearranged into appropriate columns representing sheer line, station line, buttock line, waterline and rabbet measurements. This data was then imported into DelftShip with the program recognising the offsets as coordinates and placing a point in 3D space. These lines plans shows the body plan, sheer plan and half breadth plan and they were produced using the program's 'Lines plan' function. The three plans produced of the three case studies are used to calculate coefficients and observe differences and/or similarities in the shape of the hull.

4.3 Hull design calculations

After finalising the ship's lines plans in DelftShip, the 'Design hydrostatics' function produced a report detailing the design parameters. The block coefficient, prismatic coefficient and midship coefficient were recorded for this research to illustrate changes between hull shapes.

The first, block coefficient (C_b) is the ratio between the ship's underwater volume and volume of the rectangle that encloses the hull at the level of the water line (Figure 29). The block coefficient is expressed as:

$$C_b = \frac{volume\ displacment\ of\ the\ ship}{Length\ \times Max.beam\ \times Draft}$$

The second, prismatic coefficient (C_p) is the ratio of the volume of displacement at the draft to the volume of a prism equal to the length (L) of the ship and the same cross-sectional area calculated at midships (A_m) (Figure 29). The prismatic coefficient is expressed as:

$$C_p = \frac{volume\ of\ ship}{L \times A_m}$$

The third, midship coefficient (C_m) represents the ratio of the area of the immersed cross-sectional section at midships to breadth and draft of the ship (Figure 29). The midship coefficient is expressed as:

$$C_m = \frac{Submerged\ midship\ area}{Beam\ at\ midship\ \times Draft}$$

These coefficients are used to understand changes in design and hull shape. The results from the three cases studies are presented in the next chapter. These results contribute to discussing approaches to ship design during the late eighteenth to mid nineteenth centuries.

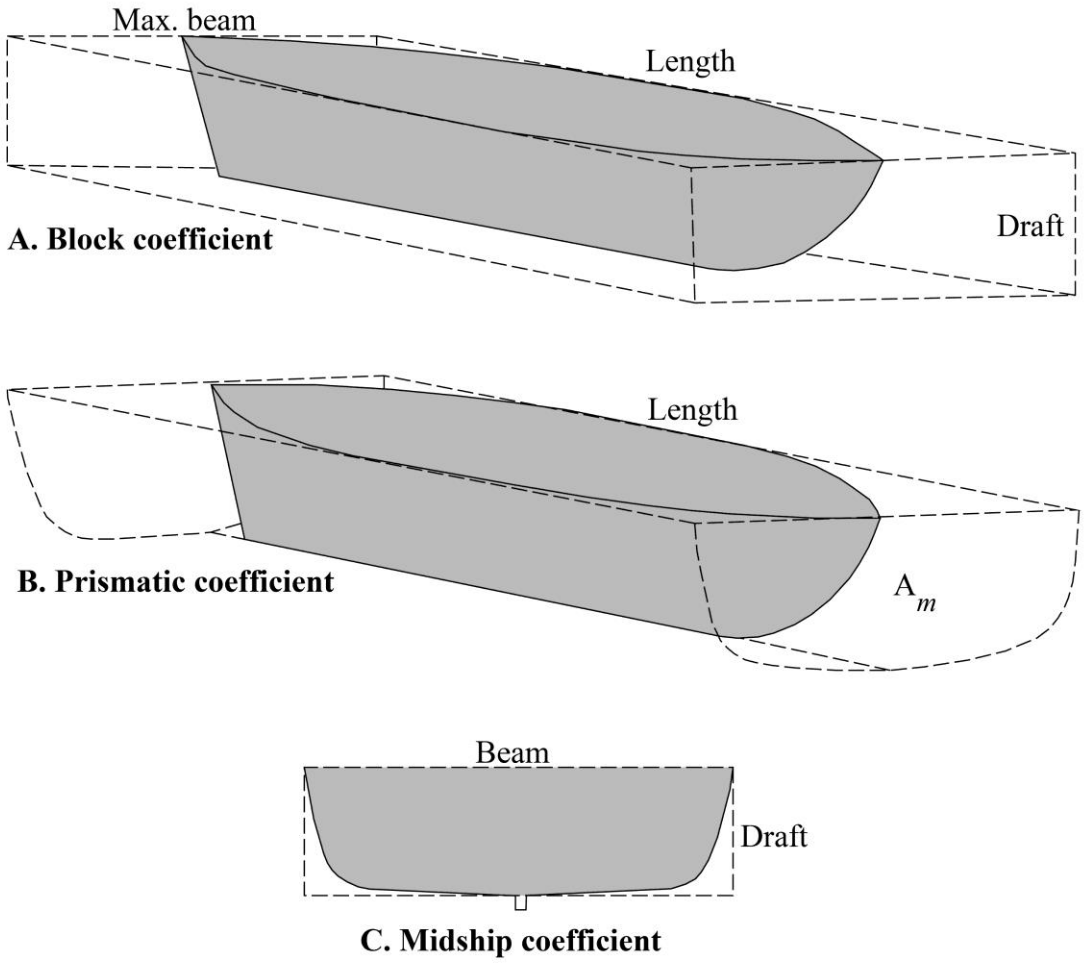

Figure 29. Block coefficient (A), prismatic coefficient (B), midship coefficient (C) diagrams (after Steffy 1994:255).

4.4 Disarticulated timbers from *Endeavour* and *Buffalo*

The researcher visited two museums to record ship timber fragments from the *Endeavour* shipwreck, located in Tamatea Dusky Sound, Fiordland, Aotearoa New Zealand. The National Museum of the Royal New Zealand Navy, located in Devonport, Tāmaki Makaurau Auckland, has in its collection a timber fragment and various pieces of ship sheathing and associated tacks. The Southland Museum and Art Gallery Niho o te Taniwha, located in Waihōpai Invercargill, has in its collection, 30 ship timbers from the *Endeavour* wreck site. These timbers range in length from 0.2 m to 3.3 m long. They were salvaged from the ship's hull in the 1970s and 1980s and then passed on to the museum in the 1990s. The *Endeavour* timbers located at both museums provide an opportunity to investigate and record eighteenth century shipbuilding commissioned by British East India Company.

4.4.1 National Museum of the Royal New Zealand Navy

The *Endeavour* timber fragment located at the Navy Museum was recorded on site at their collections warehouse, located within the grounds of the Devonport Navy base. On two different days, 14 January 2018 and 2 February 2019, the researcher visited the warehouse to record the timber fragment, accession number 2006.1631.14 SYA 0014. All sides, faces and ends of the fragment were photographed using a Canon 5D Mark III with a 24-105 f4 L lens. Photos also recorded finer details, including the woven cloth and the sheathing tacks.

Detailed photographs of the inner and outer face of the fragment were stitched together using Microsoft Image Composite Editor and then used as a digital sketch map for annotating. The image was downloaded onto an iPad and using an Apple Pencil, the researcher highlighted details on the image. The Adobe Illustrator Draw app for iPad was used to annotate the image (output JPEG) of the timber. Different colours were chosen to indicate the separate material layers, to distinguish the different features and to assist in producing the final scale drawing. For example, blue indicated nail holes and the presence of sheathing tacks, yellow highlighted tool marks, green represented resinous substances and orange signified woven material on the outer face and rust on the inner face (Figure 30). The use of the iPad as a digital notepad saved time rather than sketching the image before annotating.

Overall, the iPad lessened the time needed at the warehouse recording the timber fragment.

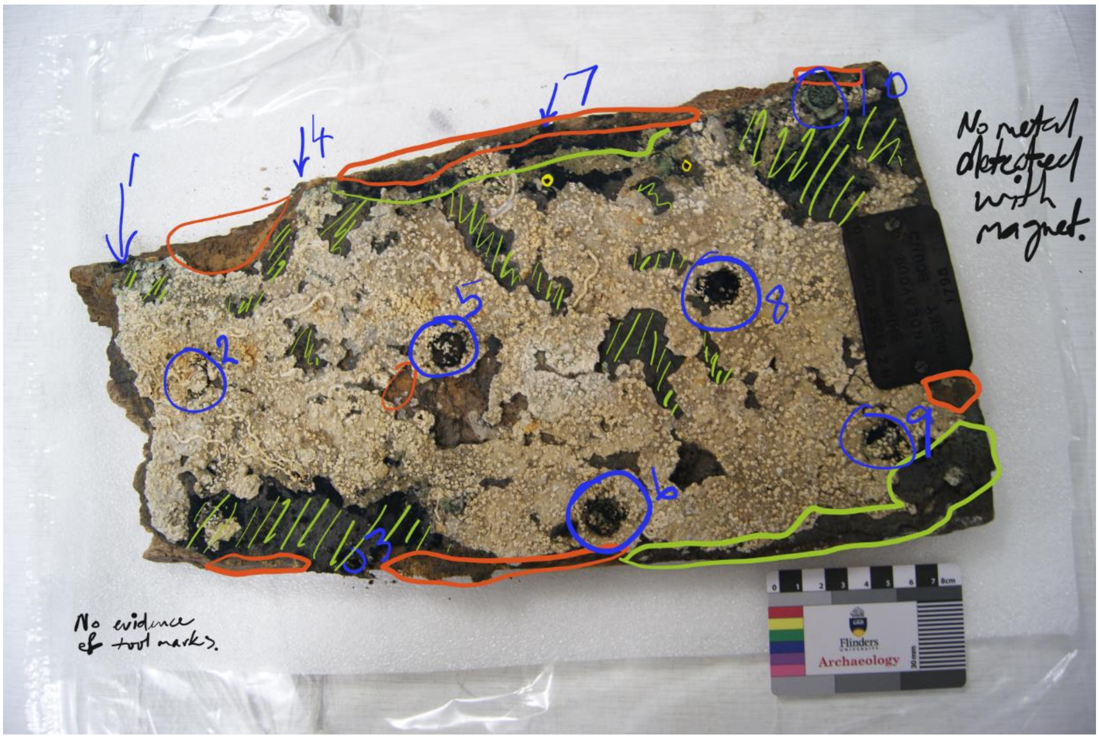

Figure 30. *Endeavour* timber fragment iPad recording screenshot.

The timber fragment was also checked for metal that may have been too degraded to see in the visual inspection. Both the inner and outer faces were checked using a 30 mm diameter by 5 mm thick neodymium (rare earth) magnet. The magnet was placed in a thin nylon sock and held at a distance of approximately 5 cm from the surface of the timber face. The use of the nylon sock allowed the researcher to hang the magnet flat above the timber while observing the movement of the magnet if it detected metal. The force of the magnet was also strong enough that the pull was felt by the researcher. To gauge the feeling and the distance, the magnet was tested on a modern iron nail prior to use on the museum artefact. This ensured the researcher knew what distance would be effective while limiting any possible damage to the ship material. Where there was no metal detected, but the wood showed possible evidence of a metal object (i.e. rust staining), the magnet was lowered until metal was detected. However, if no metal was detected, it was noted that there may have been an iron object and the evidence may be that the object was too degraded for a magnet to detect. Positive and non-positive detection was recorded on the annotated digital iPad drawing.

The timber fragment contained more detailed features which required a microscope to document the fibre and weave pattern. A Jiusion 40-1000x USB Microscope was used to inspect the woven material and to capture detailed images of the fibre. The USB microscope was connected to a laptop that used the supplied software, CoolingTech Microscope, to calibrate the images and to take the photos. The photos were saved as JPEG (Joint Photographic Experts Group) and RAW images and stored with the other *Endeavour* timber fragment images in a designated Microsoft OneDrive folder. The use of the mobile digital microscope meant materials would remain on museum premises.

The sheathing tacks' dimensions were recorded on an Excel spreadsheet. Each tack was assigned an arbitrary number in sequential order from one to 10. The numbers were used to directly correlate the individual tack with the recorded measurements. Furthermore, the numbers ensured that the tack observed on the outer face was the same as that observed on the inner face. Where the tacks were extant, two measurements were taken. The first was the width of the tack exposed on the inner face. The second was the diameter of the tack head on the outer face. Where a hole or impression indicated there was a tack, the width of the hole was measured as well as the length of the shank, where visible. Shank impressions were also observed on the edges of the timber where the timber was either degraded or had been broken during the modern salvage activity processes. In addition, the numbers assigned to each of the tacks were transcribed on to the annotated drawing on the iPad and corresponded with the object identification on the Excel spreadsheet.

4.4.2 Southland Museum and Art Gallery Niho o te Taniwha

Between 31 March and 14 April 2019, the researcher visited the Southland Museum and Art Gallery Niho o te Taniwha where 30 hull timbers from *Endeavour* are located. The museum also stores various other *Endeavour* related materials, such as loose treenails and sheathing fragments. The hull timbers showed features relating to ship construction methodologies and technologies and were documented with a variety of archaeological recording methods. The recording process followed taking detailed photographs, then measuring and recording their diagnostic features, including the production of scaled drawings. Each timber was recorded on individual recording forms designed using Filemaker pro and operated on an iPad (6th generation). The investigator was assisted by museum staff when recording the timbers.

The timbers are stored in the museum collection warehouse. The museum staff removed the materials from their storage and laid them out in the museum's gallery space specifically for this project (Figure 31). This area provided white walls which was requested by the researcher to enhance the quality of the photographs. The gallery was large enough for the researcher to walk around the timbers when recording.

Figure 31. The gallery area used for recording the timbers (Photograph: Kimberley Stephenson, April 2019).

Each timber was unwrapped from existing plastic protection and placed on to timber sawhorses prepared by the museum's technicians. The sawhorses were painted white to minimise focus issues when taking photographs while also providing support for the ship timbers. This ensured the ship materials were set at a good working height which allowed the researcher to have access to inspect five of six timber faces at any one time. This limited the required handling of the object and minimised any further damage.

Once the timbers were set up on the sawhorses, photographs were taken of each visible timber face followed by detail photographs of features relating to use of the timber in the construction of the vessel. The digital timber recording forms, aided with notes and descriptions about each face of the timber, allowed for them to be recorded in detail. In addition, the preserved dimensions, including length, width and thickness or length, sided and moulded were measured using a Stanley® 8 m retractable metal tape measure. Other details recorded on the timbers included, number of components, number of joints, types of joints, fasteners, possible wood type if it could be determined from visual inspection, conversion of timber (i.e. whole, halved, quartered, tangential and radial), bevels, construction marks, tool marks, coatings and any additional comments. Construction features were recorded using a predetermined key (see timber drawing legend).

Photogrammetry was employed to capture the *Endeavour* timbers in a 3D format. Photographs of select timbers were uploaded to Agisoft—a computer program designed to produce 3D digital models from 2D images. The result produced accurate digital models of the timbers and were saved in .OBJ format. The files were then opened in Rhino CAD software which allowed the author to determine if any matches exited between the timbers. Working in scale, breaks and fasteners holes observed in the timber were lined up to each other. This activity produced a limited digital reconstruction of the keel and allowed for further interpretation to be explored in this thesis (see *Endeavour* results chapter).

Each timber was also visually inspected for organic fibres indicating possible evidence of caulking or as external waterproofing. For metal detection, a neodymium (rare earth) magnet was used for detecting ferrous metal fasteners that were not visible to the recorder. A positive reading on the magnet was either marked as an area of 'metal detected' or as a 'fastener', if the feature could be identified.

After each timber was recorded, they were all placed in new purpose-built storage racks in the Museum's collections warehouse (Figure 32). The information collected during this fieldwork was used to update the existing archives of the Southland Museum and Art Gallery Niho o te Taniwha, the Department of Conservation Te Papa Atawhai and Heritage New Zealand Pouhere Taonga.

Figure 32. *Endeavour* timbers placed in purpose-built storage shelves (Photograph: Kimberley Stephenson, June 2019).

4.4.3 Mercury Bay Museum

The Mercury Bay Museum, located in Whitianga, Aotearoa New Zealand, was visited on three separate occasions. The first visit was between 4 and 5 November 2017, the second visit was on 26 January 2018 and the third, between 3 May and 16 May 2019. On the first visit the ship's timbers and sheathing on display in the museum's *Buffalo* exhibit were recorded. On the second visit timber samples from the ship's timbers for wood identification and a sheathing example for metal analysis were collected. After people in the local community discovered ship timbers along the main beach (Buffalo Beach) and deposited them at the museum, the third visit recorded these newly accessioned materials. It is highly probable these timbers were associated with HMS *Buffalo* and therefore, are included in this study.

4.4.4 Timber condition

As part of the timber recording, the researcher assessed the condition of the timber using a basic grading system. This provided an understanding about the level of degradation and possible reasons for limited visual diagnostic features. The grading system was divided into three categories, poor, fair and good (Table 1). The poor condition category represented 67 to 100 per cent damaged surfaces and included broken or degraded ends, edges and faces. Thirty-four to 66 per cent represented a fair condition whereby some faces were damaged or degraded with a mixture of visible and non-visible diagnostic features. A good condition displayed between zero and 33 per cent of damaged or degraded surfaces, edges and/or ends. This condition assessment is not used for purposes of discussion in this thesis, rather it acted as a guide for the researcher to understand how much of the original surface remains when post-processing the data. The condition assessment is also useful for the museum's records as a simplistic indication when staff consult with conservation specialists.

Table 1. Timber condition grading system used for recording.

Timber condition	**Per cent (%) of damaged surface area**
Poor	67–100
Fair	34–66
Good	0–33

4.4.5 Timber recording

During the first visit to the Mercury Bay Museum, the researcher measured and recorded HMS *Buffalo*'s disarticulated timbers. Three timbers were chosen for recording because they showed diagnostic features relating to construction features and could provide archaeological information specific to the assembly of the ship. The three timbers recorded were a possible deck knee, a possible false keel and a possible futtock. The second visit consisted of the researcher extracting wood and metal sheathing samples for analysis. The methods for sampling are described later in this chapter. The third visit was in response to the Museum caring for newly-found ship timbers. The investigator decided these timbers were important for inclusion as they offered more timbers to increase the dataset for comparison with the other ship case studies. All timbers were re-examined for iron fasteners using a neodymium (rare earth) magnet.

Initially, the researcher recorded timber diagnostic features on individual recording forms, including the timbers identification, evidence of fasteners, general observations and dimensions. By the third visit, the first records were input into the Filemaker Pro database and iPad recording app with the data collected from this third visit added to the electronic database. Each timber was then photographed and drawn to scale. The final drawings were produced using Adobe Illustrator CS6, showing dimensions and highlighting diagnostic constriction features in relation to the context of the timber. The timbers have since been cared for by the museum and conservation treatment is planned.

4.5 Historically preserved hull recording, *Edwin Fox*

The historic *Edwin Fox* timber hull is preserved in a purpose-built dry dock forming the main exhibit at the Edwin Fox Maritime Museum, Waitohi Picton, Aotearoa New Zealand. The hull is in a state of good preservation, with only a few components of the internal structure removed such as the beams and decking timbers prior to its relocation to the museum. The current condition of the hull presents a large and complex object to record for this study. Therefore, different recording methodologies were used to record the design of the vessel and its construction technologies.

4.5.1 Laser scanning

Between 17 and 18 December 2016, *3DScans*, an Aotearoa New Zealand company, completed 3D laser scanning of the *Edwin Fox* hull. Due to the scale and complexity of a preserved historic ship's hull, a laser scanner allowed for quick and accurate data capture. This included scanning both the internal and external hull structure (Figure 33). The company used a Faro Focus^{s} 130. The specifications of this machine are: distance accuracy ±1 mm; scanning distance from 0.6 m to 150 m; and a photo overlay up to 165 megapixel (colour). Twenty-five scanning locations were used in and around the hull to capture the entirety of the vessel, with scanning completed in two days.

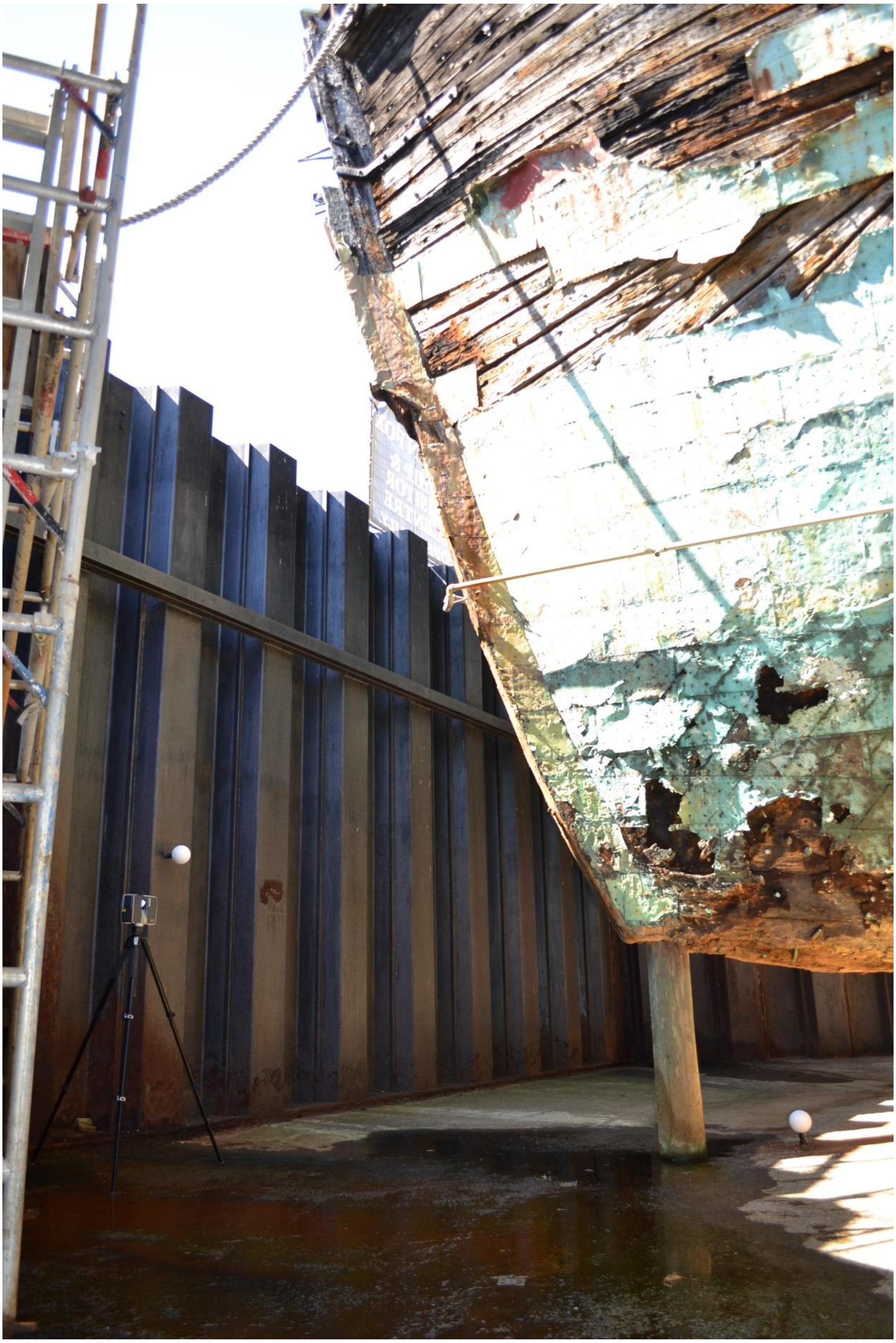

Figure 33. Faro Focus^{s} 130 positioned at the bow of *Edwin Fox* (2016).

4.5.2 3D digital modelling

Ship's lines of *Edwin Fox* were drawn from data collected by the 3D scanner. This information was post-processed using different computer software. First, the raw laser scan data was uploaded into CloudCompare and used to consolidate all the data points collected from the scan. CloudCompare is a computer program used to upload and edit point cloud data from laser scan files. The scanned data was uploaded in two parts (the external hull and the internal hull). This was because of the process in which the ship was scanned. The consolidation of data points created one image of both the external and internal hull structures.

Second, the entire digital model was saved as a geometry definition file format (.OBJ) and uploaded into MeshLab. This program is a 3D mesh editing software that helps with cleaning, converting and management of scanned data. Specifically, this software was used to reduce the overall file size and scale of the 3D digital model. The model was scaled using the Quadric Edge Collapse Decimation function to 10 per cent of the original size. The reduction in size allowed for the 3D model to become more user friendly across different platforms and programs because of its reduced file size.

The computer used for processing the laser scan data was supplied by the Digital Archaeology Laboratory at Flinders University. This computer consists of two Intel® Xeon® CPU E5-2680 v3 2.5GH$_z$ processors, 256GB RAM and operates on a 64-bit system. The computer was running Windows 10 Enterprise operating software (OS). The processing power offered by this computer is substantially more than the average house-hold computer. Therefore, the processing times for these large 3D scan files was more efficient.

Third, the reduced digital model was saved under a different name to differentiate it from the larger file of the original model. The reduced model was saved with file extension .OBJ and then imported into Rhinoceros (4.0). Rhinoceros is a computer aided design (CAD) program with previous nautical archaeological studies applying the same software (see Jones et al. 2013; Jones et al. 2017; Nayling and Jones 2012; Soe et al. 2012).Using this program, elements needed to extract measurements to produce the ship’s lines were drawn on the model. These elements include station lines, waterlines and buttock lines. Station lines are best placed along the hull at selected intervals which show change in hull shape (Steffy 1994:17). Water lines are the horizontal lines that represent the flat plane of the hull when cut at different intervals (Steffy 1994:17). It is important to note that these waterlines are construction lines only and do not represent the historic load waterlines of the vessel. The buttock lines represent the longitudinal shapes of the hull (Steffy 1994:17).

Once the 3D model of *Edwin Fox* was uploaded into Rhinoceros, the keel was traced along the *Z* axis, producing a longitudinal centreline intersecting the stem, keel and stern post. Then station lines were traced along the *X* and *Y* axis at 3 m intervals. Buttock lines were drawn along the *X* axis at 1 m, 2 m, 3 m and 4 m intervals from the centre line. They extended the height of the ship along the *Y* axis and the length of the ship along the Z axis. Waterlines were drawn starting at 3 m in height from the baseline (0 m) and added every one metre (4 m, 5 m, 6 m, 7 m and 8 m) in height on the *Y* axis. The waterlines extended the extreme width of the vessel along the *X* axis and were the length of the vessel along the *Z* axis. The rabbet was offset from the keel at 0.2 m reflecting the half width of the keel. Measurements were then recorded from where the station lines intercepted the rabbet, buttock lines, waterlines and sheer line (Figure 34). All data was entered into a Microsoft Excel spreadsheet to maintain a record of ship lines measurements and offsets. All measurements were recorded in millimetres (mm).

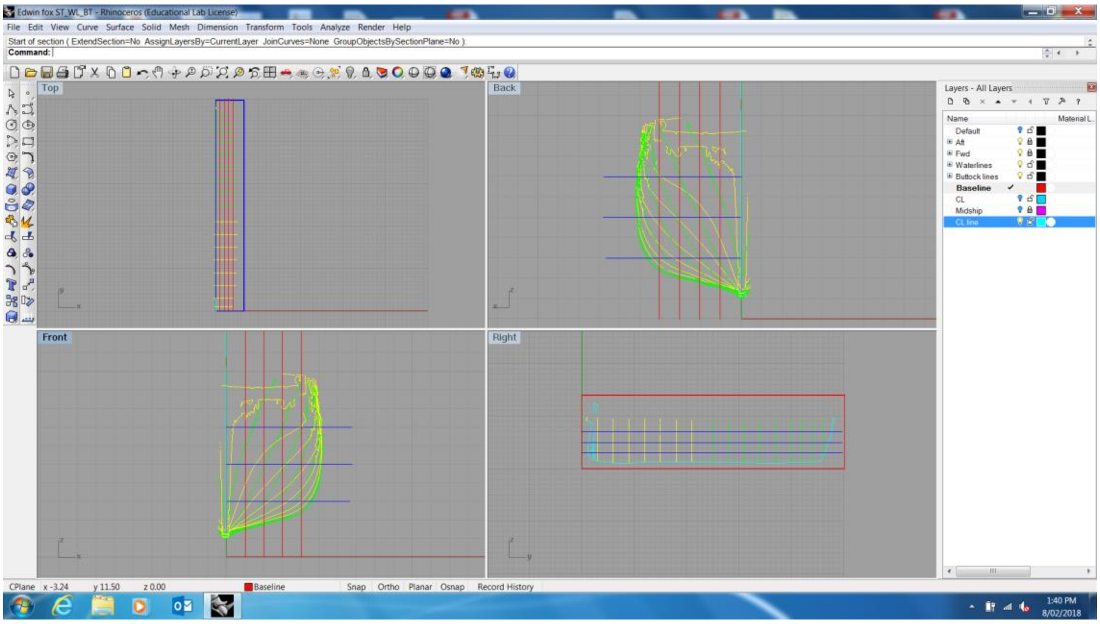

Figure 34. Station, buttock and waterlines intersecting the 3D digital *Edwin Fox* hull model.

4.5.3 Profile construction drawing

A profile view of *Edwin Fox* was drawn from the 3D digital model. This cross-section revealed construction features used in the ship's hull and provides context to each of the structural elements. Meshlab was used to cut the 3D digital model longitudinally along the keel and extreme length between the bow and stern. The half model now showing the internal and external hull structure was converted into an orthographic projection. This flattened the 3D image to be viewed as a 2D image. The orthographic projection was imported into Adobe Illustrator CS6 as a base layer. Additional layers were then added to represent the different ship components. For example, keel, floor timbers, keelson, sister keelson, futtocks, planking, stanchions, breast hooks, knee riders, masts and deck beams. The profile construction drawing was drawn as it was recorded by the laser scan in December 2016. However, known missing timbers were included as a dashed line to distinguish between what once existed and what currently exists in the ship's hull. Structural elements that could not be viewed in the 3D digital model or that were inaccessible during onsite recording have also been drawn with a dashed line to represent the components that could exist.

4.5.4 Midship construction drawing

Between 18 and 24 April 2017, volunteer maritime archaeologists Katarina Jerbić and Matthew Carter joined the author to record the midship section of the *Edwin Fox* hull. The team established the location of the midship by calculating the middle from the existing length of ship's hull between the forward and aft perpendiculars. A baseline was established along the *X* axis, both with a chalk line and a levelled string line. A 30 m fibreglass tape measure was attached to the string line and extended from the dry dock's west wall to the east wall. Two baselines were established along the *Y* axis on port and starboard sides intersecting with the *X* axis baseline. A plumb bob and tape measure was used as the vertical height (*Y* axis) offset measurement along the underside of the keel (*X* axis), while a laser distance measurer instrument was used as the horizontal distance (*X* axis) offset measurement along the vertical port and starboard sides (*Y* axis) (Figure 35 and Figure 36). Approximately 20 points were measured at a time to ensure mistakes could be easily identified and amended as they were translated onto the scaled drawing.

Figure 35. Using a laser distance unit to measure the port side of the *Edwin Fox* hull (2017).

Figure 36. Katarina Jerbić and Matt Carter establishing the external baseline across the X axis at midships on the *Edwin Fox* hull (2017).

Once the recording of external hull points was completed, the midship line was transferred to inside the vessel's hull. This was achieved by using a laser level to accurately transfer the *Y* axis against both the port and starboard sides of the ship. A string line was then secured around the ship's exterior to create a semi-permanent midship section line. From this line, three baselines were established in the interior. One baseline followed the *X* axis, traversing the keelson, floor timbers, framing and hold planking (Figure 37). The *Y* axis baselines then intersected the *X* axis baseline and extended vertically up both the port and starboard internal sides of the ship. Measurements to hull features were taken using an offset method. A plumb bob was used to measure heights from the *X* axis baseline, while a tape measure and a spirit level were attached to a pole to measure the distances from the *Y* axis baselines.

Figure 37. Establishing the internal midship lines inside the *Edwin Fox* hull (2017).

All measurements were recorded in a separate field notebook and then plotted onto A1 sized drafting film. Grid paper was laid beneath to provide a reference guide for scaling. A scale of 1:20 was chosen as this maximised the piece of drafting film. The midship section was drawn on site at the time of recording to ensure any mistakes could be rectified. The finished drawing was scanned at Warehouse Stationary, Wairau Park, Auckland, Aotearoa New Zealand and preserved digitally in both JPEG and TIFF file formats. These digital copies were processed in Adobe

Illustrator CS6 to clean the images for final publication and are presented in the results chapter. In addition, the midship drawing is used as a site plan for dendrochronology locations as well as providing contextual cross-sectional data of the hull assembly.

4.5.5 Keelson recording

During the January fieldwork in 2018, the keelson and sister keelson were recorded between the forward mast and extended 5 m aft of the main mast. The purpose of this recording was to capture the relationship between the keelson and sister keelson, the timber joints and carpenters' or tool marks. A baseline was established above the keelson and attached to the stanchions on top of the sister keel (Figure 38). The baseline consisted of a 30 m fibreglass measuring tape and was levelled using a string-line level. Offset measurements were taken from the baseline to points and features along the keelson and sister keelson for recording. Where there were no evident features, offset measurements were recorded at 0.5 m intervals to capture the contour of the timber components. The measurements were plotted on graph paper at a scale of 1:20 at the same time of recording. The graph paper and scaled drawing was scanned and uploaded to Adobe Illustrator CS6 where the lines were cleaned for inclusion in the results chapter.

Figure 38. Baseline offset method for recording the keelson (2018).

4.5.6 Ship timber catalogue

To compare timber dimensions between the three case studies (*Endeavour*, HMS *Buffalo* and *Edwin Fox*), a timber catalogue was created for components recorded on *Edwin Fox*. An Excel spreadsheet was created to store the timber identification assigned by the researcher, timber dimensions and additional notes. The catalogue is adapted from the description discussed by Sheila Matthews (2004:78–79) and developed after Steffy (1994:207). Therefore, the catalogue is organised into six sub-categories to suit the size and complexity of *Edwin Fox*:

1. stem, stern post, keel, keelson and sister keelson;
2. floors, futtocks and wales;
3. deadwood and breast hooks;
4. external and ceiling planking;
5. masts, stanchions and deck beams; and
6. unclassified.

Labelling of the *Edwin Fox* timbers followed the traditional system used by shipwrights and previous nautical archaeological investigations. Matthews (2004:76–77) described this system—applied to the *Serçe Limanı* shipwreck—as labelling the frames forward of midships with letters in consecutive order and those frames aft numbered in the same order. Then, all frames are given an F prefix and futtocks a suffix. Additional components such as the keel, knees and wales were assigned letters. Under each sub category, timbers were assigned a unique identifying code, the remaining moulded and sided dimensions of each timber were measured, floor and futtock spacing were measured, identification of fastener type, dimensions and sequence were identified, tool marks (if any) were recorded, types of joints described and dimensions measured and additional comments about each timber, if relevant.

Specific to the recording of *Edwin Fox*, only the midships was recorded as a representative sample of the collection of hull timbers. The area of recorded planks is limited to the lengths of the planks that intersect the midship line. Therefore, the *Edwin Fox* timber catalogue represents the midship area of timbers only. In addition, the unique identifying code was transcribed on the profile construction drawing to provide further context about the structural component. The full catalogue is too large to be presented in a readable format. Instead, digital copies have been lodged with their respective museums (Appendix 1).

4.6 Wood identification

The three ship's timbers recorded for diagnostic features were sampled to identify timber species. Extraction methods included making two parallel cuts using a hand saw and then chiselling out the sample. Also, priority was given to sampling loosely attached timber as this limited the need to damage or modify the timbers. The samples were then sanded and polished using sandpaper ranging between 180 and 800 grit to expose the timber cell structure. The timber samples collected measured approximately 2 cm^3 allowing for enough material to be examined under a microscope.

Edwin Fox was sampled using two methods. The first included using a carpenter's saw, a hammer and a chisel to collect a sample approximately 2 cubic centimetres (cm^3) from the second outer layer of planking. The second method involved drilling cores for dendrochronology to act as wood samples for identification. The timber samples were sanded until a polished surface exposed the cell structure for examination under microscope. Timber specialist, Rod Wallace, University of Auckland Te Whare Wānanga o Tāmaki Makaurau, inspected the timber samples.

4.7 Dendrochronology

Gretel Boswijk, a dendrochronologist and senior lecturer in Environment, Faculty of Science, University of Auckland Te Whare Wānanga o Tāmaki Makaurau, provided training and equipment for the dendrochronological sampling of *Edwin Fox*. Standard methods were used for coring (Boswijk 2009; Boswijk et al. 2014; Boswijk and Johns 2018; Boswijk and Jones 2012). Equipment used for coring included a 5 mm diameter handcorer and two 10 mm diameter steel corers used with an 18V cordless Makita power drill. Collection of the samples was conducted between 3 and 5 September 2017 and the midship section of the hull was targeted for samples. In total, ten samples were extracted and included, keel, keelson, floor timbers, sister keelson, frames, planking and main mast (Figure 39). Each sample was labelled with prefix 'EFX' followed by sequential numbers as the cores were extracted. Where possible, timber features were cored from both sides to capture the entire cross-section of the timber ring pattern. Each sample was placed in individual plastic straws to ensure the integrity of the core and all samples were transported back to the Tree-ring Lab at the University of Auckland.

Figure 39. Kurt Bennett extracting a core from the keelson aft of the main mast (2017).

For the tree-rings to be counted, each sample was prepared by exposing the tree-rings along a horizontal plane. This involved gluing each sample to a purpose cut cradle and then sanding each sample in half. Between 17 September and 31 October 2017, the researcher first used coarse grained sandpaper (180 grit) and gradually progressed to using more fine sandpaper (800 grit). The finer sandpaper ensured the sample was left with a polished finish and this helped to make the visual identification of the tree-rings easier.

Once the cores were prepared, they were individually placed on a stage under a microscope. The stage moved left to right under the control of the researcher. Each ring was counted by visually inspecting the sample and location of the tree-rings. The distance between each ring was electronically measured and recorded on specialist software, TsapWIN. Each sample gave its own unique display of distances between the tree-rings. Further statistical analysis calculated which core samples related to each other in terms of species to then be compared with corresponding chronologies. The master chronologies used were 'Burma Teak', 'Java Teak' and 'Thai Teak' provided by Martin Bridge (Institute of Archaeology, University College of London). On completion of this research, the core samples have been returned to their respective museum locations.

4.7.1 Timber conversion

This research identified how ship timbers were converted from the parent tree during the milling process. For this study, five categories depicting cross-sectional conversions were adopted from a previous tree-ring study (Figure 40) (Hillam 2015). A whole timber represents minimal shaping and milling. Halved is where the tree has been usually split into two and maximising the original girth. Quartering is the result of milling a tree into four approximately equally sized timbers. Tangential timber conversion requires the milling process to saw through opposite sides of the sap wood to produce planks. Radial conversion mills the timber in a sequence that follows the perimeter cutting from the sap wood to the pith and results in angled cut timbers.

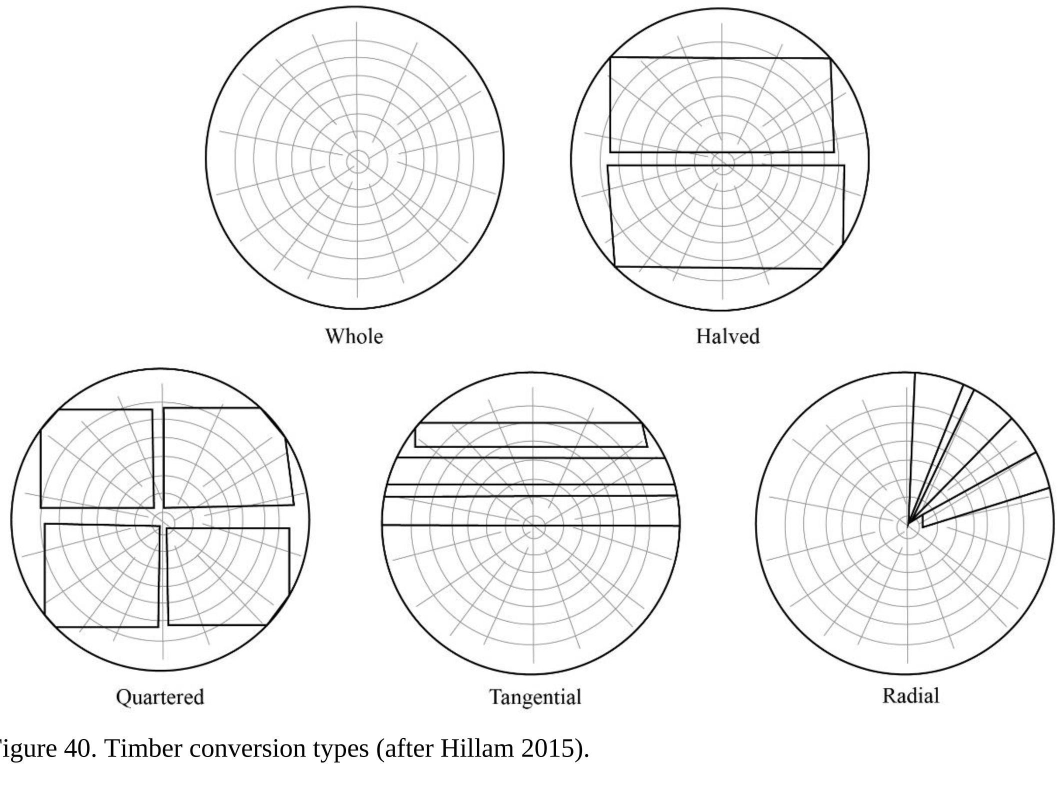

Figure 40. Timber conversion types (after Hillam 2015).

4.8 Metal analysis

Metal sheathing samples were collected from the three vessels and they measured approximately <1 cm^3. Depending on the museum, either the researcher, conservator or collection managers collected the samples for analysis. The metal analyses were undertaken by Wendy van Duivenvoorde using a Quanta 450 FEG Environmental Scanning Electron Microscope with an Oxford Ultim Max EDS Detector at Adelaide Microscopy, South Australia. The Quanta 450 is a High-Resolution Field Emission Scanning Electron and is used to image and analyse surface topography, collect backscattered electron images and characterise and determine a sample's elemental composition through x-ray detection with an SD EDS detector. The results are semi-quantitative and assist the study of sheathing metal compositions of antifouling technologies.

The project team collected six sheathing samples from both the port and starboard sides at the bow, midships and stern of the *Edwin Fox* hull (Figure 41). The size of samples measured approximately 60 mm in length by 40 mm wide and <1.5 mm thick. In addition, a representative sample of sheathing tacks was collected for analysis.

Figure 41. Kurt Bennett cutting a metal sheathing sample from the *Edwin Fox* hull (Photograph: Katarina Jerbić, 2017).

Metal sheathing and tacks were embedded in Struers Multifast phenolic hot mounting resin for general use. The resin and metal were set in a Struers CitoPress-10 hot mounting machine. The resin mounts and embedded samples were then polished using a Struers TegraPol-11 diamond polisher to expose uncorroded surfaces for analyses (Figure 42).

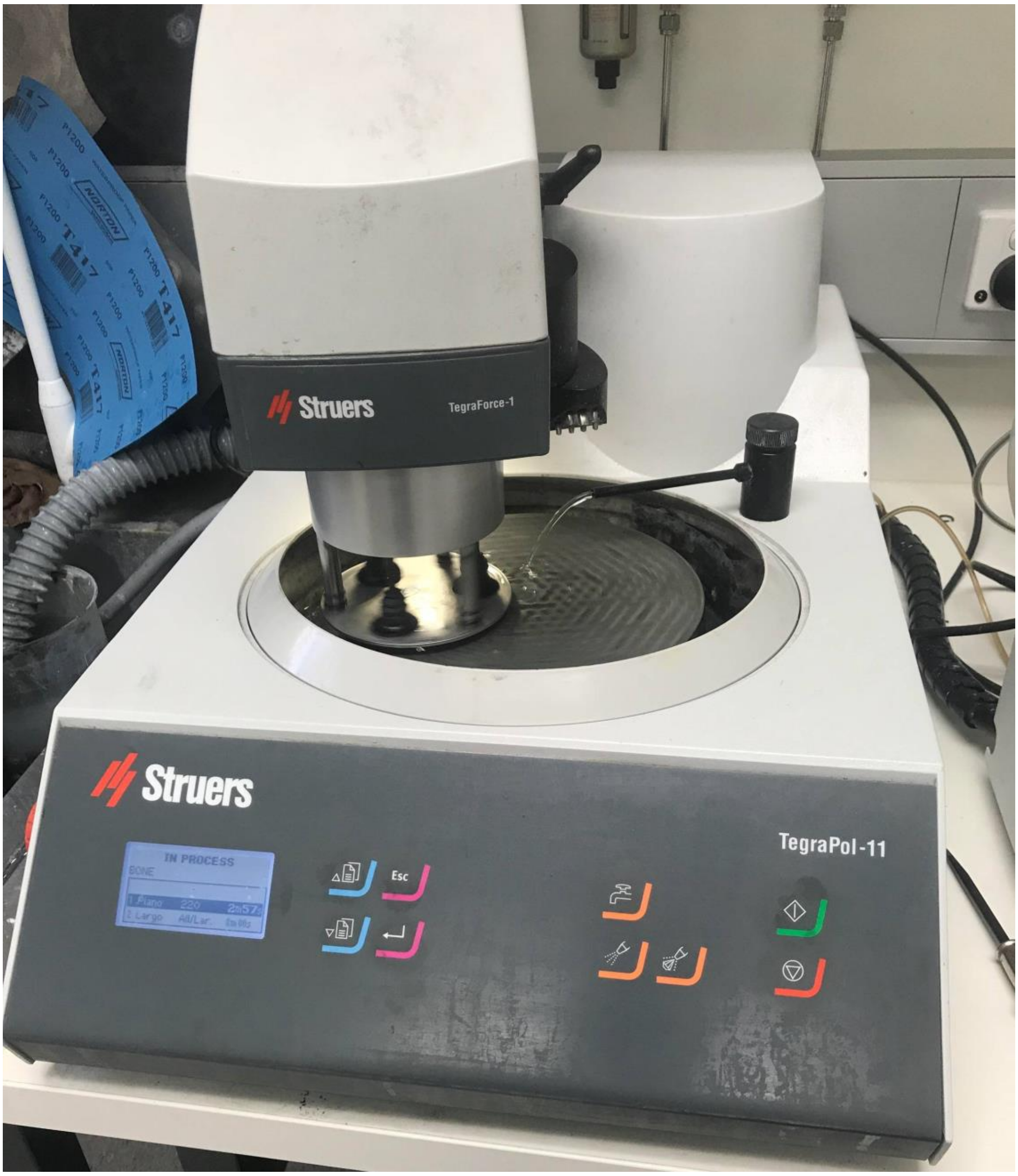

Figure 42. Struers TegraPol-11 diamond polisher (Photograph: Wendy van Duivenvoorde, 2019).

The FEG Quanta 450 with SDD EDS detector allows for a semi-quantitative analytical method of elemental composition by spot or area testing (Figure 43). This method means that the analysis is a targeted testing method and is not necessarily representative in composition of an entire sample. It was aimed to test three areas per sample to ensure similar compositions as a representative sample. Areas from the polished sample that were free of corrosion product and displayed solid metal were chosen for elemental determination.

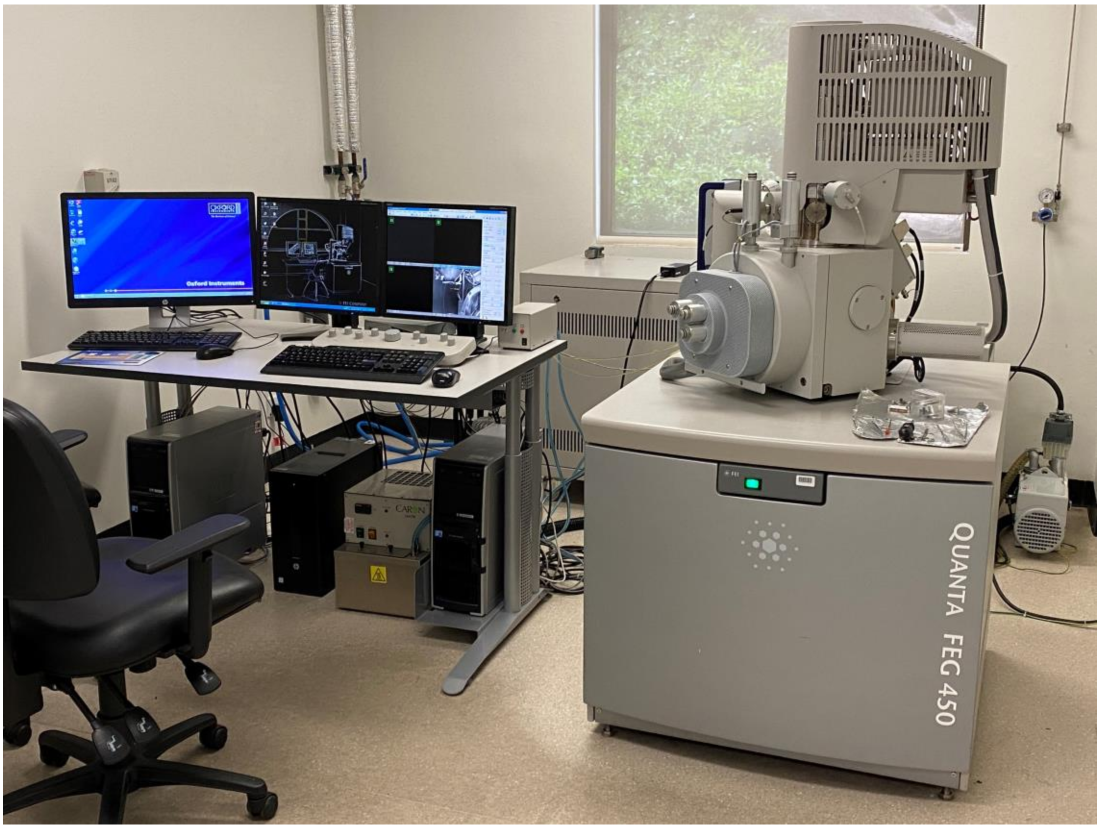

Figure 43. FEG Quanta 450 with SDD EDS detector (Photograph: Wendy van Duivenvoorde, 2019).

For data acquisition the following SEM settings were used: High-Vacuum, kilovoltage: kV 20, Elemental Normalized, SEC table: default, standardless. The Quanta 450 is the fastest SEM EDS collector in Australia and therefore, the time per sample analysis was automated.

4.8.1 Metal sheathing placement and stamp recording

The museum *Buffalo* display contains a total of eleven pieces of ship sheathing that were available for recording. Included in the total number and counted as one piece of sheathing were the sheets of sheathing attached to the sister keel. The other ten recordings were individual pieces that have been retrieved from the shipwreck or have washed up on the nearby Buffalo Beach (Rebecca Cox pers. comm. 2017). The dimensions, sheathing tacks (if present) and maker’s marks or stamps for each piece of sheathing were recorded on individual recording forms.

The *Edwin Fox* research team inspected the hull for evidence of copper sheathing patent stamps, government marks and sheathing orientation. Bingeman et al.'s (2000:227) paper illustrated a range of patent stamps and government marks evident on nineteenth-century English naval vessels and this catalogue was used to aid the identification of marks observed on the hull sheathing. Furthermore, Staniforth (1985:29–31) discussed the methods of positioning the copper sheets to the ships' hull. The methods include overlapping, direction of overlapping and different fasteners. The size and orientation of the copper sheathing on *Edwin Fox* was recorded with a representative sample drawn to illustrate the sheathing and fastener patterning.

At the conclusion of this research, all the metal samples were returned to the museum from which they came from. The samples will remain in storage and can be made available for future research and interpretation. The results of this analysis provide insights into the differences in metal antifouling technologies between the three cases studies and contribute to future investigations as examples of sheathing technologies relating to late-eighteenth- and mid-nineteenth-century vessels.

4.9 Fibre identification

The *Endeavour* timber fragment held by the National Museum of the Royal New Zealand Navy contained a woven fabric matting between the timber and metal sheathing. Working with a conservator from the Museum, a small sample was extracted of this material. In addition, fibres were collected from ship timbers at the Southland Museum and Art Gallery Niho o te Taniwha. Then, fibre samples were collected from *Edwin Fox* during the April 2017 field work. Samples from two different features included the caulking between the outer planking and the fibrous matting applied between the outer planking and the copper sheathing. Each sample measured approximately 3 cm^2 in area. Prior to sending for analysis, the fibre samples were photographed using a USB microscope. Sub samples taken from the larger submitted samples were removed and a few dozen hairs were analysed with a transmission light microscope with a polarised light option. The hairs and fibres were identified using identification guides and reference collections of animal hair and plant fibres at BIAX Consultancy. Once the fibres were analysed, the results were emailed to the researcher for inclusion in this study and the samples returned. No fibres were available for sampling on the HMS *Buffalo* timbers.

BIAX has over 15 years of experience specialising in archaeo- and palaeobotany and has experience working with samples taken from both terrestrial and marine environments, in particular shipwreck sites. One or two loose strings of fibre from the edge of the sample was used for analysis and examined by a trained professional. Henk van Haaster, BIAX consultant, identified the origin of the fibre through examining the cell structure and comparing that to BIAX's existing fibre catalogue. The sample and the individual fibres extracted for examination were returned to the Museum to be stored for future research and/or public interpretation. The sample was not destroyed during this process.

4.10 Organic analysis

The resinous samples collected from *Endeavour*, HMS *Buffalo* and *Edwin Fox* were analysed by Jordan Spangler of the School of Chemistry and Physical Sciences at Flinders University, South Australia. Prolysis-gas chromatography was used to analyse organic compounds, namely pitch samples collected from the ships' structures. This method involves the chemical analysis of the sample through heating it and dividing it into smaller molecules. Hexamethyldisilazane (HMDS) is used as a treatment agent for samples prior to the injection into the GC-pyroliser. Trimethylsilane (TMS), when combined with HMDS, protects phenols, alcohols and carboxylic acids. These groups have a high stability due to inter molecular hydrogen bonding. If left unprotected, they will raise the stability of the compound to a level where pyrolysis is unsuccessful. Therefore, it is essential for these groups to be protected with HMDS and TMS. Thus, TMS derived compounds identified in the mass spectra are assumed to have originated as their unprotected dialogues.
Five µL of hexamethyldisilazane (HMDS) was added to the sample and pyrolysed at 550 degrees Celsius (pyrolysis time: 20s). The pyrolyser (Frontier Lab PY-3030 S Single shot pyrolyser) was coupled online with an Agilent Technologies 789013 GC System Gas Chromatograph coupled with an Agilent Technologies 5977B GC/MSD mass spectrometer. The pyrolyser interface was kept at 180°C, the transfer line at 300°C and the valve oven at 290°C. For the gas chromatographic separation, an

Agilent 190915-433 HP-5MS 5% Phenyl Methyl Silox (29.4m x 250 µm x 0.25 µm) column was used. The split–splitless injector was used in split mode at 300°C, with a split ratio of 1:15. The chromatographic conditions were as follows: 30°C isothermal for 8 minutes, 10°C per minute up to 240°C, isothermal for 3 minutes, 20°C per minute up to 300°C and isothermal for 30 min. The carrier gas (He, purity 99.9995%) was used in the constant flow mode at 1.0 mL per minute.

4.11 Photography

A Sony Alpha DSLR-A230 camera and a Canon 5D Mark III with a 24-105 f4 L lens were used during the fieldwork. Photographic red and white scales measuring 1 m (0.2 m increments), 0.5 m (0.1 m increments), 25 cm (1 cm increments), 10 cm (1 cm increments), 5 cm (1 cm increments) and a Department of Archaeology, Flinders University 8 cm photographic scale card were used in images where appropriate. The cameras were used to capture the research team activities, contextual images and detailed images of ship features. Specifically, the images provide a photographic record of the vessel at the time of recording while also demonstrating contextual and detailed information to complement the descriptions for this research.

4.12 Conclusions

Each of the three archaeological case studies used for this study represent different assemblages of materials available for recording and documenting. This required a range of methods to be used to record the timbers and associated ship structure from *Endeavour*, HMS *Buffalo* and *Edwin Fox* with consistency in method used as much as possible. The combination of methods applied to the three case studies allowed the researcher to assess design elements and to analyse construction technologies being used during the late-eighteenth and early- to mid-nineteenth centuries.

Through the combination of archival research, ship lines drawings, scaled timber feature drawings, laser scanning, digital computer aided design (CAD) drawings, construction drawings, timber identification, dendrochronology, metal analysis, fibre analysis, organic analysis and photography, this study answers the main research question in two parts. First, this investigation determines how the ship's hull of

British East Indiaman changed over time. Second, how the adaptation to local timber resources influenced the development of ship design. Furthermore, archival research contextualises the social, political and economic reasons for the cause to establish foreign shipyards and the use of unfamiliar timbers in new regions. Specifically, this research contributes to understanding BEIC ship manufacture during the late-eighteenth and nineteenth centuries. The results produced from the archival research and fieldwork described in this chapter is discussed in the following chapters, outlining the three case studies.

Chapter 5. *Endeavour* results

This chapter presents the results collected for this research in order to understand the design elements and construction technologies when building *Endeavour*. Results from fieldwork start with timber fragments in order to describe their function, condition, joint, dimensions, fasteners, surface coverings, markings and sampling. Certain terms have been used to define elements of the timbers. The use of 'face' refers to the different sides of the timbers and are numbered to reflect the corresponding drawings. This allows for individual faces to be described where the identification of the inner or outer faces are not apparent. The term 'surface covering' refers to any evidence of metal, fibrous, organic material or substance that has been applied to the timber surface. These can include resinous compounds, fibre matting or metal sheathing. This section is then followed by wood identification, metal analysis, fibre identification and organic analysis. The results for *Endeavour* are separated into two sub-sections that reflect the museum collections visited for this investigation.

5.1 Historical findings and hull design

Historical research shows *Endeavour* was constructed in the year 1771 under the name *Lord North* ([BL] IOR/L/MAR/C/529:20). Records note, *Lord North* was built on the bottom of *Fort St George*[10] on the River Thames by shipwright [John] Wells under the ship's husband, John Durand ([BL] IOR/L/MAR/C/529:20). *Lord North*'s scantlings from historical documents are presented in Table 2 with metric conversions.

Table 2. Scantling dimensions as recorded for *Lord North* (*Endeavour*) ([BL] IOR/L/MAR/C/529:20).

Description	Metres	Feet	Inches	Tons
Length overall	42.31	138	9 ¾	
Keel length for tonnage	33.87	111	3/2	
Extreme breadth	11.04	36	3	
Depth of hold	4.33	14	5/2	
Tonnage by measurement				777 74/94

[10] *Fort St George* sailed three return voyages between 1740 and 1747 and is likely to be the named vessel which preceded *Lord North* (Sutton 2000:150).

The earliest requested record refers to Captain William Hambly being sworn into command *Lord North* on 5 September 1770 prior to the vessel's construction[11]. *Lord North* sailed a total of five return voyages for the Company. It set sail on its first voyage from 'The Downs'[12] to 'Coast and Bay'[13] on 28 March 1771 and returned 13 September 1772. The second voyage sailed to Bencoolen and China, departing The Downs, 27 December 1774 and returned 7 June 1776. The third voyage to Madras departed 'Ports.[mouth]', 15 July 1777 and returned to The Downs, 16 November 1779. Court documents dated 10 March 1780 state *Lord North* was damaged and *Mountstuart* was taken up as a replacement vessel ([BL] L.R.264.b.3:i) inevitably delaying its fourth voyage. *Lord North* was 'driven on shore [at Deptford], has lost the season, and as her repairs will be attended with a considerable expense to the Owners' ([BL] L.R.264.b.3:14–15). A note dated 17 May 1780 states '*Lord North* to be repaired for a fourth voyage, and the Court to reserve a right of deciding whether she [it] shall be taken up for any greater number.' A tender was read on 23 June 1780 and the fourth voyage sailed for Bencoolen and China from Portsmouth, 13 March 1781 and returned to The Downs, 21 February 1783. On 17 September 1783, *Lord North* was tendered for a voyage out and stipulated to be on the terms that could be agreed between the Owners and Court. By 12 May 1784, however, ship tenders of *La Menagerie*, *Tartar*, *Lord North*, *Chapman* and *Locko* were rejected. On 11 June 1784, *Lord North* was again tendered for a voyage out, on terms agreed between a Mr Preston and the Court. It is possible Mr Preston and the Court disagreed as there is no record of a voyage taking place in the next year. By 22 June 1785, Mr Preston offered to repair *Lord North*, 'if she [it] is wanted' indicating the ship may have become slightly degraded. Then in the following year, the fifth voyage, this time to China departed from The Downs, 26 April 1786 and returned 27 July 1787. John Bartlet captained the vessel and John Durand remained as the ship's husband ([BL] ORB 30/889). On 26 October 1787, *Lord North* was '…tendered for a voyage to India, at £1,200 for the run, and to be sold there.'

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[11] The author searched archival documents at the British Library for *Endeavour*'s vessel history and to confirm its original date of construction. *Endeavour* was traced through its previous name, *Lord North* (Boocock and Kenderdine 1992:2). Available journals for *Lord North* ([BL] IOR/L/MAR/B494A and [BL] IOR/L/MAR/B494E) were reviewed, however, they contained no information relating to the construction of the ship and its eventual sale.

[12] An area off the coast of Kent, England, where merchant ships would wait for the required conditions to sail up the River Thames.

[13] The area that includes the Coromandel Coast and the Bay of Bengal (Cotton 1949:47).

> London, 26th October 1787
> Honorable sirs,
> We beg leave to tender the ship *Lord North* (which had a thorough repair last voyage) John Bartlet to continue Commander; to carry out goods, merchandize and passengers from England to any part in India, by the run (and to be discharged there for sale to a British subject) at the freight of £12000 [possible error in text]. For the run; two-thirds thereof to be paid within three months after the ship's departure from England, and the other one-third part upon her arrival at Madras, or port of discharge in India. The ship to be navigated with 70 men; the Commander and Officers to be allowed the customary privilege outward, and to be allowed demorage, as usual, during her stay in England after the period fixed for her departure, and one shilling per day each passenger on board for fresh provisions whilst in harbour. The said ship to have her bottom coppered, and fitted to your satisfaction, under the inspection of your own surveyors and servants.
> We have the honor to be with great respect, Honorable Sirs,
> Your most obedient humble servants,
> John Durand.
> John Bartlet.
> ([BL] L.R.264.b.3:502, Appendix, No.939).

Archival records show the registered tonnage for same vessel are inconsistent over time. When reading the registers of the ship's voyages, it was observed that the tonnage of the vessel became greater in relation to its final voyages. The first voyage registered 499 tons, the second, third and fourth 761 tons and the fifth 758 tons ([BL] ORB 30/889).

Although no descriptions of *Lord North*'s original construction were found, short entries dating around 1785 and 1786 briefly describe an extensive repair or partial rebuild of the ship (Table 3). It appears *Lord North* had almost a complete rebuild prior to its fifth and final voyage for the company and is likely to have contributed to its longevity. These descriptions describe the type of work or activity that was happening at the time along with the number of shipwrights employed. This is useful because it gives us insight into the method of construction, the timeframe and the labour involved to construct the ship during the mid-1780s.

Table 3. *Lord North* undergoing extensive repairs and partial rebuild between 1785 and 1786 ([BL] L.R.264.b.3:Appendix 575, 612, 641, 653, 661, 702, 739, 762, 778 and 783, 824).

Date	**Activity**	**Shipwrights employed**
9 February 1785	Keel laid.	Unrecorded
6 January 1786	Trimming the floor timber.	10
10 February 1786	Trimming the frame timbers.	8
8 March 1786	Stem and stern frame up and all floors across.	10
7 April 1786	22 pairs of frames up.	20
5 May 1786	Two thirds timbered.	20
9 June 1786	Works timbered, chocked and dubbed.	20
7 July 1786	Works wales worked and 16 strikes under.	30
4 August 1786	Works kneeing the lower deck.	30
8 September 1786	Works working ‘ditto’ (upper deck) clamps.	40
6 October 1786	Works working the round-house clamps.	40
13 December 1786	Ready to launch.	12

Lord North, constructed in 1771, is confirmed to be the same ship later renamed *Endeavour* that was eventually abandoned in Tamatea Dusky Sound, Aotearoa New Zealand. The ship sailed five voyages for the Company before being ‘sold for breaking up’ in 1787 but survived as a merchant vessel trading between India and Australia before its eventual abandonment in 1795 (Hackman 2001:148–149).

5.1.1 Hull lines

No hull plans exist for *Endeavour* from which to directly reproduce ship’s lines. After searching the British Library, National Archives and the Caird Library in London for the lines plans of *Endeavour*, none were found. It was decided to illustrate the approximate shape of *Endeavour*’s hull with a lines plan produced from around the same time as the ship was built. The lines plan is reproduced from a drawing produced in Fredrick Henrick af Chapman’s (2006:Pl. LI) *Architectura Navalis Mercatoria: The Classic of Eighteenth-Century Naval Architecture* (Figure 44 and Figure 45). The plan’s measurements are presented in feet to reflect the original drawings dimensions. This data will be used to compare with the other case studies’ ships plans to assess the shapes of the hulls. Furthermore, it provides new contextual information for the Southland Museum and Art Gallery Niho o te Taniwha’s timber collection.

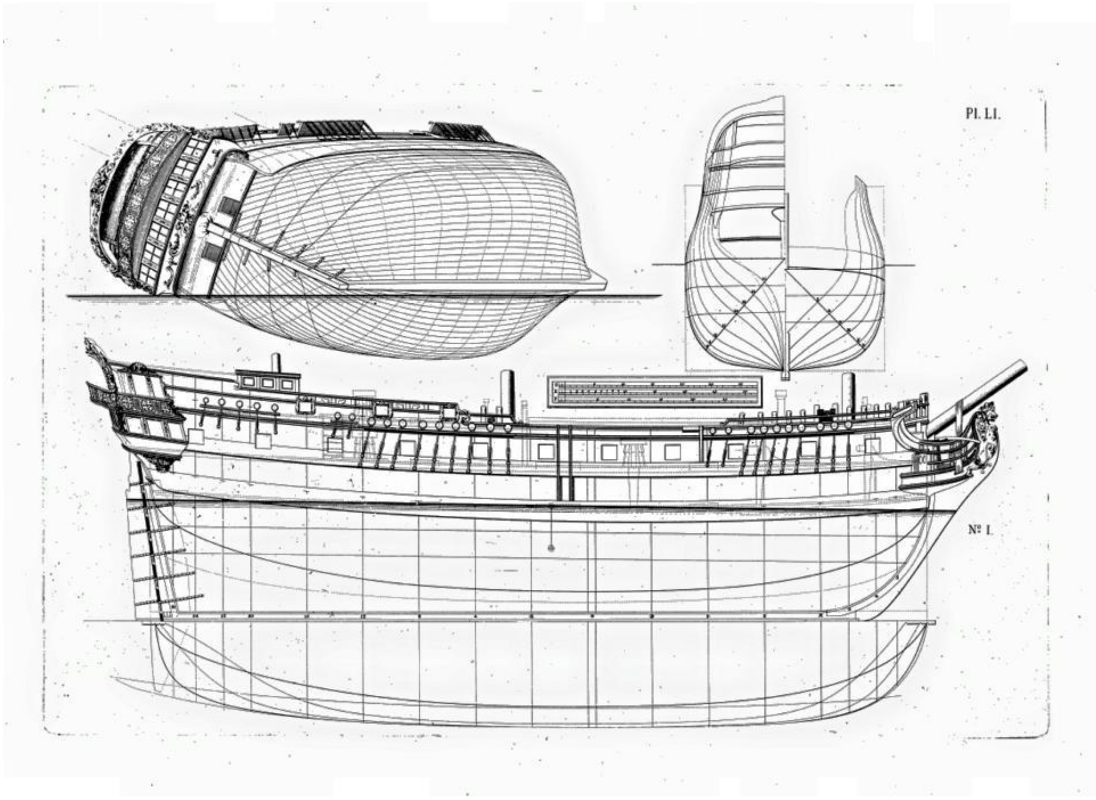

Figure 44. An English East Indiaman c.1760s (after Chapman 2006:Pl. LI).

5.1.2 Hull coefficients

The completed lines plan provides the parameters to calculate hull coefficients. The block coefficient is equal to 0.6258, the prismatic coefficient is equal to 0.7381 and the midship coefficient is equal to 0.8478. These coefficients determine the ratios of area/volume of the hull when compared to the equivalent area/volume of water and are used to assess changes in shape over time.

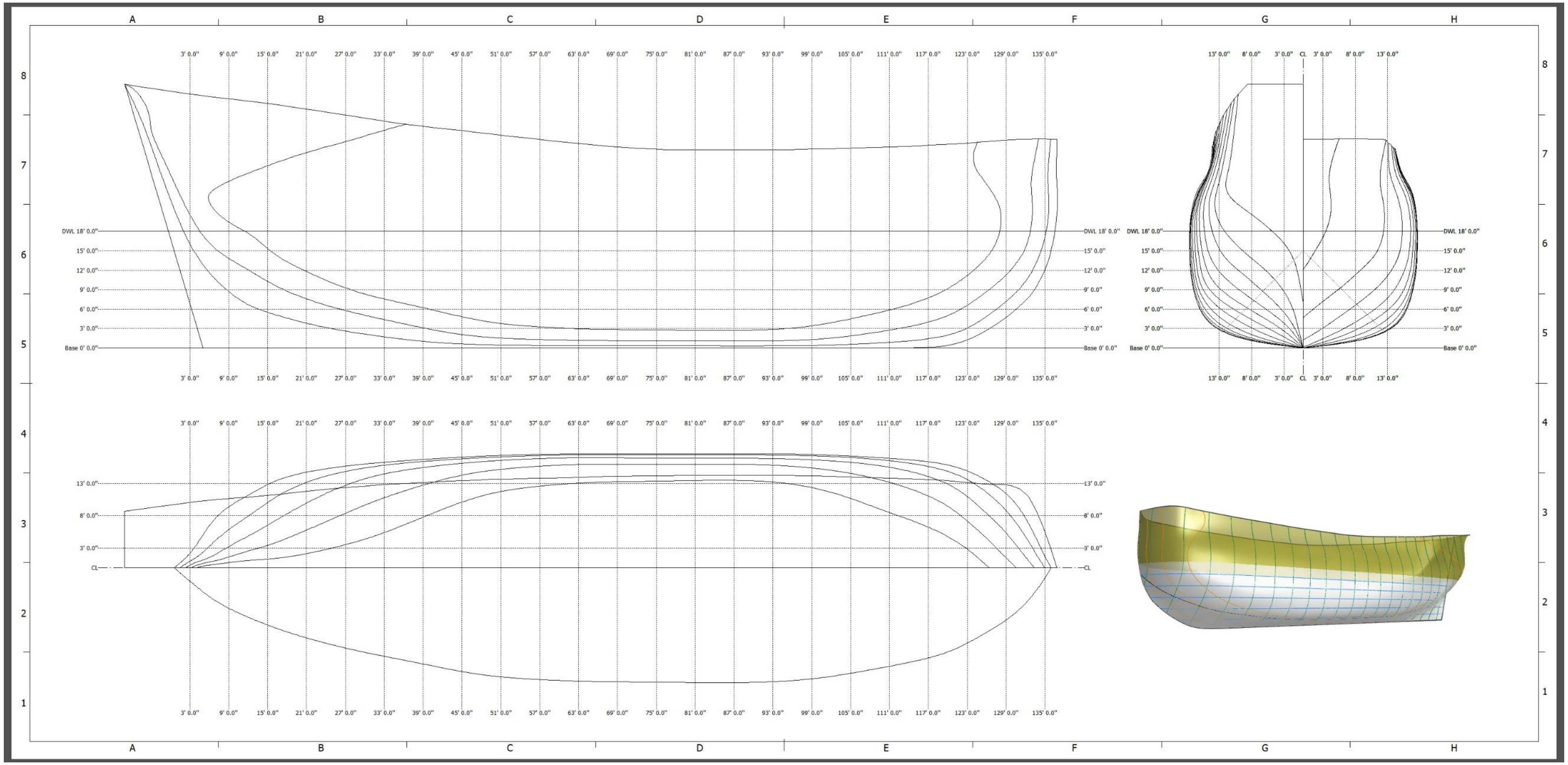

Figure 45. Lines plan of *Endeavour* based on Chapman’s drawing.

5.2 National Museum of the Royal New Zealand Navy

A timber fragment collected from the shipwreck *Endeavour* in Tamatea Dusky Sound is stored at the Navy Museum collections warehouse. The timber fragment's accession number is 2006.1631.14; SYA 0014 and is not on public display. The piece of planking showed multiple layers of diagnostic features that directly contribute to this study of ship technologies and to understanding how late-eighteenth century ships were constructed.

5.2.1 Sacrificial timber sheathing

This identified sheathing plank fragment measured 385 mm in length by 203 mm in width and 30 mm thick. It retained evidence of a fabric layer and copper sheathing on the outer face of the timber (Figures 46 and 47). One end shows clear sawing activity demonstrated by saw marks which is likely caused by the modern removal from the original structure. The other end is badly degraded due to the effects of marine organisms and the copper sheathing is heavily corroded.

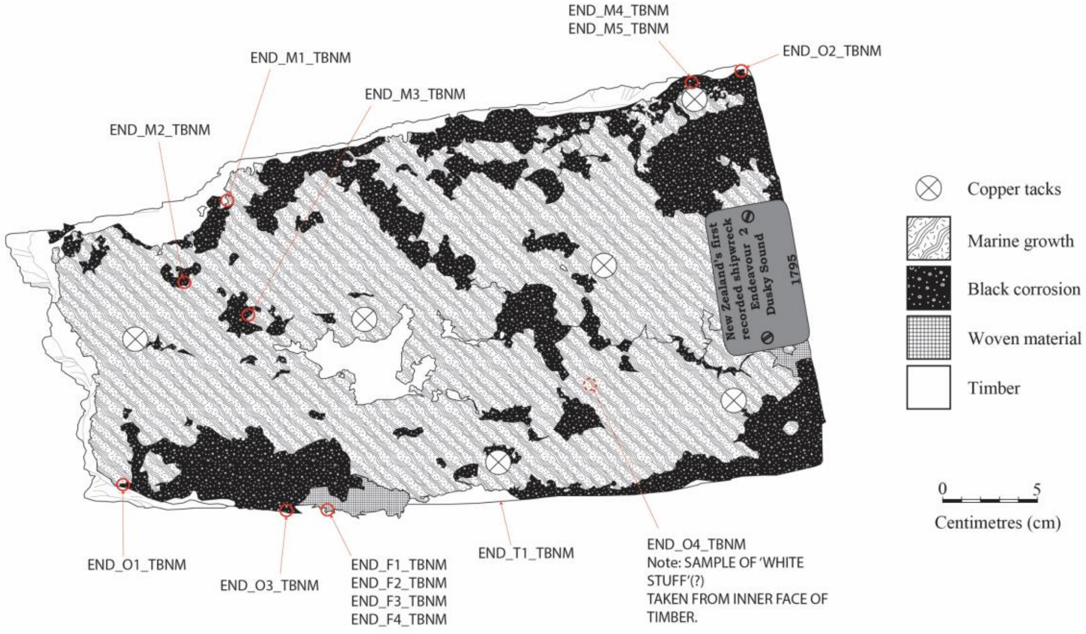

Figure 46. Outer face of the *Endeavour* timber fragment recorded at the National Museum of the Royal New Zealand Navy.

Figure 47. Sacrificial timber (2006.1631.14; SYA 0014) held in collection at the National Museum of the Royal New Zealand Navy (2018).

On the outer face of the timber is a layered antifouling structure. This includes a woven matting in a crisscross pattern with each thread measuring 0.1 mm in diameter (Figure 48). The fabric is adhered to the timber using an organic compound. This organic layer was applied directly below the metal sheathing. The sheathing is highly degraded and contains little to no original metal; however, sheathing tacks are present with copper oxidation indicating the area of sheathing coverage. A total of nine sheathing tacks were observed on the inner surface and 10 tacks on the outer surface of the timber. The shanks measured an overall length of 27.5 mm with the head diameters measuring between 13 mm and 14 mm. The positioning of the tacks in the timber resembled a crisscross pattern.

Figure 48. Woven matting recorded on *Endeavour*'s sacrificial timber fragment (2006.1631.14; SYA 0014) held in collection at the National Museum of the Royal New Zealand Navy (thread = 1 mm).

Furthermore, possible iron staining suggests there may have been ferrous fasteners embedded in the timber. Both the inner and outer faces were checked with a magnet for ferrous metals, with no positive detection. No tool marks or maker's marks were observed on the timber.

5.2.2 Wood identification

This timber fragment was not sampled for wood identification. After consultation with collections manager, Claire Freeman, and conservator, Rose Evans, it was decided that sampling the timber would damage the plank fragment. Upon visual inspection, the wood is likely to be teak but this remains unconfirmed to date.

5.2.3 Metal analysis

The conservator collected four metal samples from the metal sheathing and were sent to Flinders University for archaeometallurgical analyses. Wendy van Duivenvoorde embedded the samples in resin which were then polished for analysis. When first polished, however, it became clear that the samples contained no original metal and only corrosion products. Therefore, no results were obtained from the metal samples collected from the Navy Museum's *Endeavour* timber fragment. No sheathing tacks were extracted for analysis in order to maintain the overall aesthetics of the plank fragment.

5.2.4 Fibre identification

Fibre samples from the matting between the timber and the metal sheathing were identified by BIAX Consultants, the Netherlands (Table 4). The fibre is woven using small bundles of spun wool and measure between 10 and 20 microns in diameter. The spun wool is woven in a 1/1 plain weave pattern (Taylor 1991:77). The species from which the wool came could not be determined.

Table 4. Fibre sample from the *Endeavour* timber fragment, National Museum of the Royal New Zealand Navy.

Sample #	**Accession #**	**Function**	**Fibre**	**Description**
F1	2006.1631.14; SYA 0014	Sacrificial planking	Wool	Spun wool

5.2.5 Organic analysis

This timber contained a layer of a pitch-like substance between the metal sheathing and sacrificial timber plank. Embedded in the organic compound is a woven fibre matting with results presented previously. The conservator collected four samples of the organic compound from different locations on the timber as original material could not be determined. The four samples provided the best opportunity to analyse the substances while minimising the risk of returning an unsuccessful result. The results of the four samples collected from the same timber are presented below (Table 5).

Table 5. Pitch results from the *Endeavour* sacrificial timber fragment (2006.1631.14; SYA 0014).

Sample ID	**Compound**	**Retention time (minutes)**
END_O1_TBNM	3-aminohydro-2(3H)-furanone, TBDMS	14.3
	TMS derived arsenous acid	15.8
	1,3,5-cycloheptatriene-7,7-dimethyl-2-4-bis(TMSM)	19.6
	TMS derived palmitic acid	29.1
	Methyl 6-dehydrodehydroabietate	33.2
	Dehydroabietic acid, TMS	33.5
END_O2_TBNM	3-aminohydro-2(3H)-furanone, TBDMS	14.3
	TMS derived Arsenous acid	15.8
	TMS derived p-coumaric acid	19.6
	TMS derived palmitic acid	29.1
	TMS derived stearic acid	31.3
	Epimethendiol-diOTMS	32.5
	5,8,11-Eicosatriyonic acid, TMS	33.4
END_O3_TBNM	TMS derived palmitic acid	29.1
	Methyl 6-dehydrodehydoabietate	33.1
	Dehydroabietic acid, TMS	33.5
END_O4_TBNM	No compounds observed	NA

The pitch results from the *Endeavour* samples indicate long chain fatty acids with dehydroabietic acid and methyldehydroabietate. These elements are probably associated with tar produced from organic resins. The results of the pitch and its application on the hull are addressed in the discussion chapter.

5.3 Southland Museum and Art Gallery Niho o te Taniwha

Between 1 April and 14 April 2019, the researcher visited the Southland Museum and Art Gallery Niho o te Taniwha, located in Waihōpai Invercargill, Aotearoa New Zealand. The Museum has in its collection several artefacts that have been collected from the *Endeavour* ship site in Tamatea Dusky Sound. These items range from large ship timbers to smaller fragments and individual fasteners. The researcher spent two weeks recording the items which displayed diagnostic features that aid this study. The results from the individual recorded timbers with measurements are summarised below (Table 6). The list follows the arbitrary registration numbers (END_001, END_002, etc) assigned by the researcher chronologically in the order they were recorded. The description of each timber is then presented according to their function. The wood identification and metal, fibre and organic analyses then follow.

Table 6. Summarised *Endeavour* timber dimensions, Southland Museum and Art Gallery Niho o te Taniwha.

ID	Accession #	Feature	Length (mm)	Moulded/ Width (mm)	Sided (mm)	Thickness (mm)
END_001	95.71.1 [48557]	False keel	3163	305	138	
END_002	95.71.1 [48557]	Keel	3385	**374**	**369**	
END_003	95.71.2 (a) [81939]	Keel	2215	**365**	**364**	
END_004	83.2002	Sacrificial sheathing	3285	280		31
END_005	83.2002 (b)	Sacrificial sheathing	615	21		21
END_006	95.71.3 (a) [81952]	Unidentified	3083	365	135	
END_007	95.71.15 (a) [81952]	Futtock	2025	295	199	
END_008	95.71.16 (a) [81953]	Unidentified	1146	185	**105**	
END_009	95.71.18 (a) [81954]	Unidentified	1306	174	85	
END_010	95.71.18 (a) [81955]	Outer plank	1942	**261**		**101**
END_011	95.71.19 (a) [81956]	Plank	1548	160		**105**
END_012	95.71.20 (a) [81957]	Plank	1528	308		105
END_013	95.71.21 (a) [81958]	Futtock	1188	**192**	132	
END_014	95.71.22 (a) [81959]	Outer plank	1189	**215**		**105**
END_015	95.71.23 [81960]	Keel	1381	183	179	
END_016	95.71.24 (a) [81961]	Outer plank	1562	**234**		90
END_017	95.71.10 (a) [81947]	Keel	1598	327	98	
END_018	95.71.4 (a) [81941]	Outer plank	3284	**307**		**91**
END_019	95.71.5 (a) [81943]	Garboard strake	2945	**291**		**114**
END_020	95.71.6 (a) [81943]	Outer plank	2122	**320**		**100**
END_021	95.71.11 (a) [81948]	Outer plank	2656	**260**		**98**
END_022	95.71.9 [81946]	Outer plank	676	137		102
END_023	95.71.12	Outer plank	1396	224		**98**
END_024	95.71.7 (a) [81944]	Outer plank	2354	**273**		**98**
END_025	95.71.8 [81945]	Outer plank	1252	**276**		**98**
END_026	95.71.14 (a) [81951]	Keel	1274	188	262	
END_027	0000.3754 [62501]	Plank	1065	**286**		**63**
END_028	83.2115.1 [63366]	Outer plank	760	146		63
END_029	97.75	Sacrificial sheathing	201	232		**24**
END_030	2004.938.243	Sacrificial sheathing	484	265		**24**
END_031	95.71.13 [81950]	Undiagnostic	416	95	40	
END_032	95.71.4 (d) [81941]	Plank fragment	283	84		65
END_033	95.71.25 (b) [81962]	Undiagnostic	169	60	40	
END_034	95.71.25 (b) [81962]	Undiagnostic	233	76	55	
NB: **Bold** = maximum original measurements.						

5.3.1 Keel and false keel

5.3.1.1 END_001 false keel fragment

This false keel timber is attached to END_002 (keel fragment), which provided contextual information (Figure 49). The timber is in poor condition as it is badly degraded at one end. Preserved dimensions measured a length of 3,163 mm, 305 mm moulded and 138 mm sided. The conversion of the timber was halved and displayed evidence of a butt joint at one end. Extant and non-extant evidence of fastener types included metal bolts, metal nails and metal staples. The round fasteners are likely keel bolts as they extend through END_001 and END_002 on a vertical axis. The bolts had a maximum diameter of 33 mm and measured 800 mm in length. Square iron fasteners, detected by the magnet, measured 10 mm by 11 mm with the overall length unknown due to them being embedded in the timber. These extended on a vertical axis through END_001 into END_002. Evidence of possible metal staples exist with right-angled impressions in the timber. The hole of the possible staples measured 10 mm by 11 mm in area. The magnet detected two round iron bolts and measured 50 mm in diameter. There is also evidence of a possible washer or a larger bolt head measuring a maximum 61 mm in diameter. No construction or tool marks were visible as the timber's surfaces were too badly degraded.

The presence of sheathing tack impressions indicates there was once metal sheathing applied to the timber, although none existed for recording. The holes left by the sheathing tacks were square in shape and varied in depth up to 28 mm. The distances between tacks were not measured because there was no clear patterning. The false keel was sampled for wood identification.

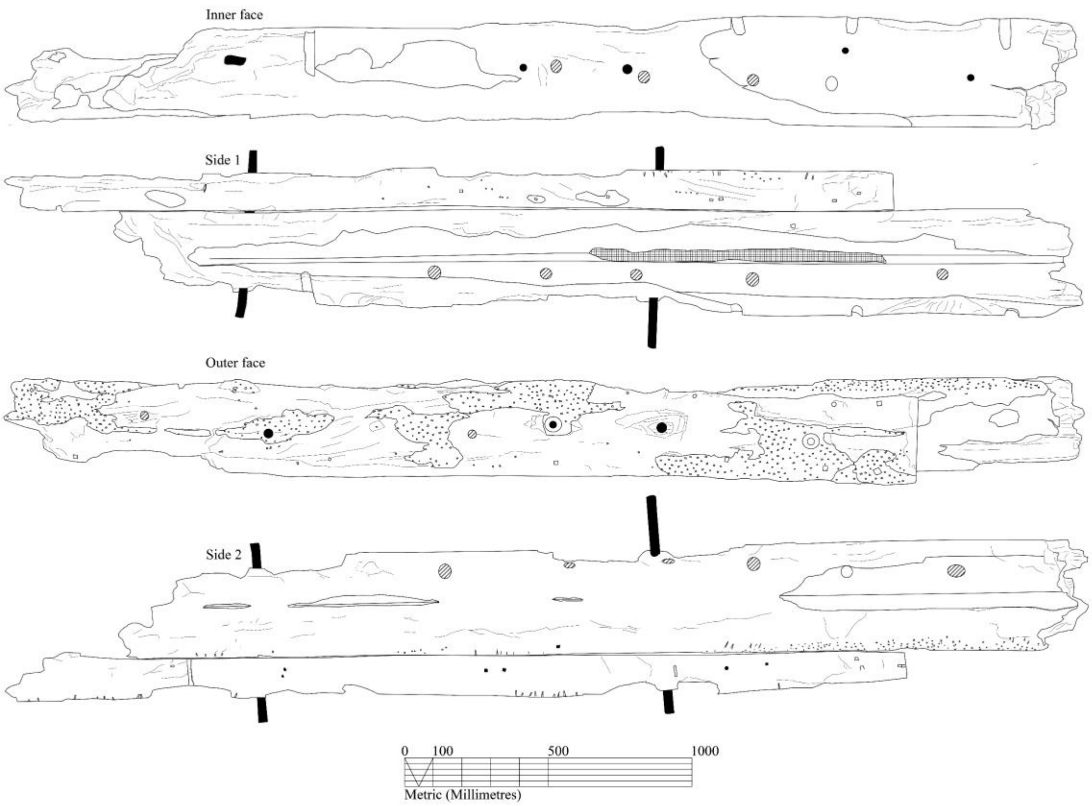

Figure 49. END_001 false keel and END_002 keel fragment drawing.

5.3.1.2 END_002 keel fragment

The researcher identified the function of this timber as a broken piece of keel which is attached to the false keel (END_001) described previously (Figure 49). The timber is approximately 70 per cent degraded on the surface and is in poor condition. The preserved length of the timber measured 3,385 mm whereas the maximum moulded face measured 374 mm and sided 369 mm. The keel was probably converted as a whole from the parent tree. There was no sap or bark present. Two large alloy keel bolts (described previously) extend through the timber. No timber joints were identified due to one end being heavily degraded and the other appearing broken. This timber displayed rabbet lines on both sides recorded as Side 1 and Side 2. The distance from the bottom of the keel to the outer rabbet line measured 182 mm. The angles of the rabbet on face 1 measured 39 degrees on the rabbet and 50 degrees along the back rabbet. The angles on face 2 measured 26.6 degrees on the rabbet and 55.6 degrees along the back rabbet. The bottom measurements cut into the keel approximately 92 mm and the top measurement cut in approximately 137 mm. The timber also contained different fastenings, including treenails and metal bolts. A total of 11 treenails exist in the timber and measured approximately 41 mm in diameter. These treenails showed no evidence of wedges as the exposed ends were either degraded or had broken off. Their total lengths could not be measured as the treenails are still inserted into the main keel timber and could not be removed for recording. Additionally, there are both square and round iron and alloy fasteners. The round fasteners are keel bolts measuring 32–33 mm in diameter by 800 mm long. No tool marks or construction marks were recorded.

Surface covering evidence was recorded as organic remains. This appeared to be plant-based material and was evident along the rabbet lines as a type of caulking. No metal sheathing was present, although there are impressions of small square tacks—a continuation of the impressions recorded on END_001. Depths of the holes varied and were recorded as having an approximate maximum depth of 27 mm. The distances between tacks were not measured as there was no clear pattern of arrangement. Wood and fibre samples were collected for identification.

5.3.1.3 END_003 keel fragment

This timber is a broken longitudinal piece of keel (Figure 50). One end is broken, and the break is similar to the broken end on END_002. The timber is slightly weathered and is in a fair condition. The timber measured a preserved length of 2,215 mm. The maximum moulded face measured 365 mm by a maximum 364 mm sided. The original tree was converted as a whole with no bark or sap wood remaining. A diagnostic feature on this timber is evidence of a tabled scarf joint orientated vertically and extending longitudinally along the keel timber. The presence of rabbet lines further suggests this timber fragment is a continuation of END_002. The distance from the bottom of the keel to the outer rabbet line measured an approximate height of 187 mm. Angled recesses were evident at both ends of the timber on face 1 and were measured to determine changes in inclination. The rabbet angles of face 1 measured 23.3 degrees at end 2 and 33.5 degrees at end 1 (broken end). The back rabbet angles measured 72 degrees at end 2 and 58 degrees at end 1. The angles on face 3 were measured on one end of the timber and to where the scarf joint started. At end 1, the rabbet angle measured 34 degrees and 32 degrees at end 2. The back rabbet angles measured 59 degrees at end 1 and 65.6 degrees towards end 2. The depths of the rabbet cut into the keel measured approximately 107 mm and the depths of back rabbet measured approximately 175 mm. Treenails and metal fastenings were present in the timber. A total of five treenails were present and measured 43 mm in diameter. Their lengths could not be measured due to being stuck in the timber. No treenail wedges were present because the ends were either broken off or degraded. Empty bolts holes are positioned vertically through the inner face to the outer face. The diameters of the holes measured 35 mm and are similar in their characteristics to the alloy keel bolts recorded on END_001 and END_002. The magnet detected iron metal in the form of possible iron spikes. While tool marks were present, no construction marks were recorded. Impressions left by a tool measured 27 mm by 11 mm in area and are associated with round tool marks which arc through two of the impressions. It could not be determined if these tool marks were from the original construction or from contemporary salvage activity. In addition, there is evidence of adze workings along the entire length of the inner face.

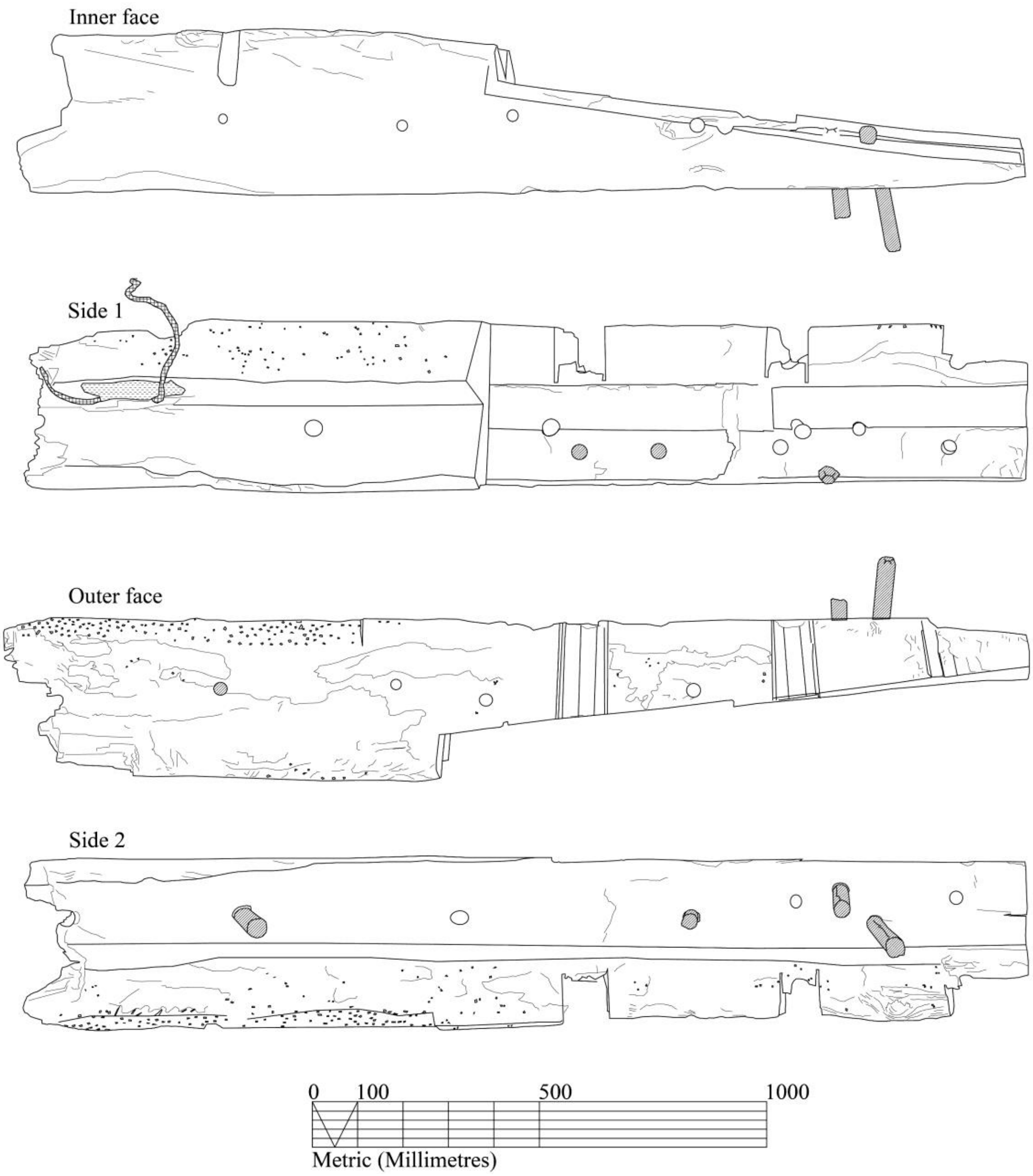

Figure 50. END_003 keel fragment drawing.

Organic surface coverings exist along the rabbet lines and appear similar to the possible caulking recorded on END_002. Impressions of sheathing tacks are also present in the timber along the outer faces of the timber. The holes are square in shape and range in size due to the depths in which they have been hammered into the timber. The voids measured up to 26 mm in depth. A wood sample was collected for timber identification along with a fibre sample from the possible caulking.

5.3.1.4 END_015 keel fragment

This keel fragment is part of the larger scarf joint associated with END_002 (Figure 51). One face of the timber is clearly split from the original timber and is likely to be a result of modern salvage activity. The condition of the timber is in a poor state of preservation. Due to the timber having broken and worked edges it was not possible to identify how the timber was converted. The preserved dimensions of the timber measured 1381 mm in length by 183 mm moulded and 179 mm sided. A rabbet line is present on one face of the timber and measured between 64.8 degrees to 73 degrees. The length of the rabbet line could not be measured because neither side was preserved. Treenails and evidence of metal fasteners are present in the timber. The one extant treenail measured 40 mm in diameter with no wedge present. The timber contains one round ferrous metal fastener that measures 33 mm in diameter. The exact length of the fastener was not measured as it was corroded at both ends. No surface coverings were present on the timber and no evidence of sheathing tack holes were observed. The recesses on the scarf joint were recorded as construction marks. The recesses measured 23 mm deep by 13 mm. No samples were collected.

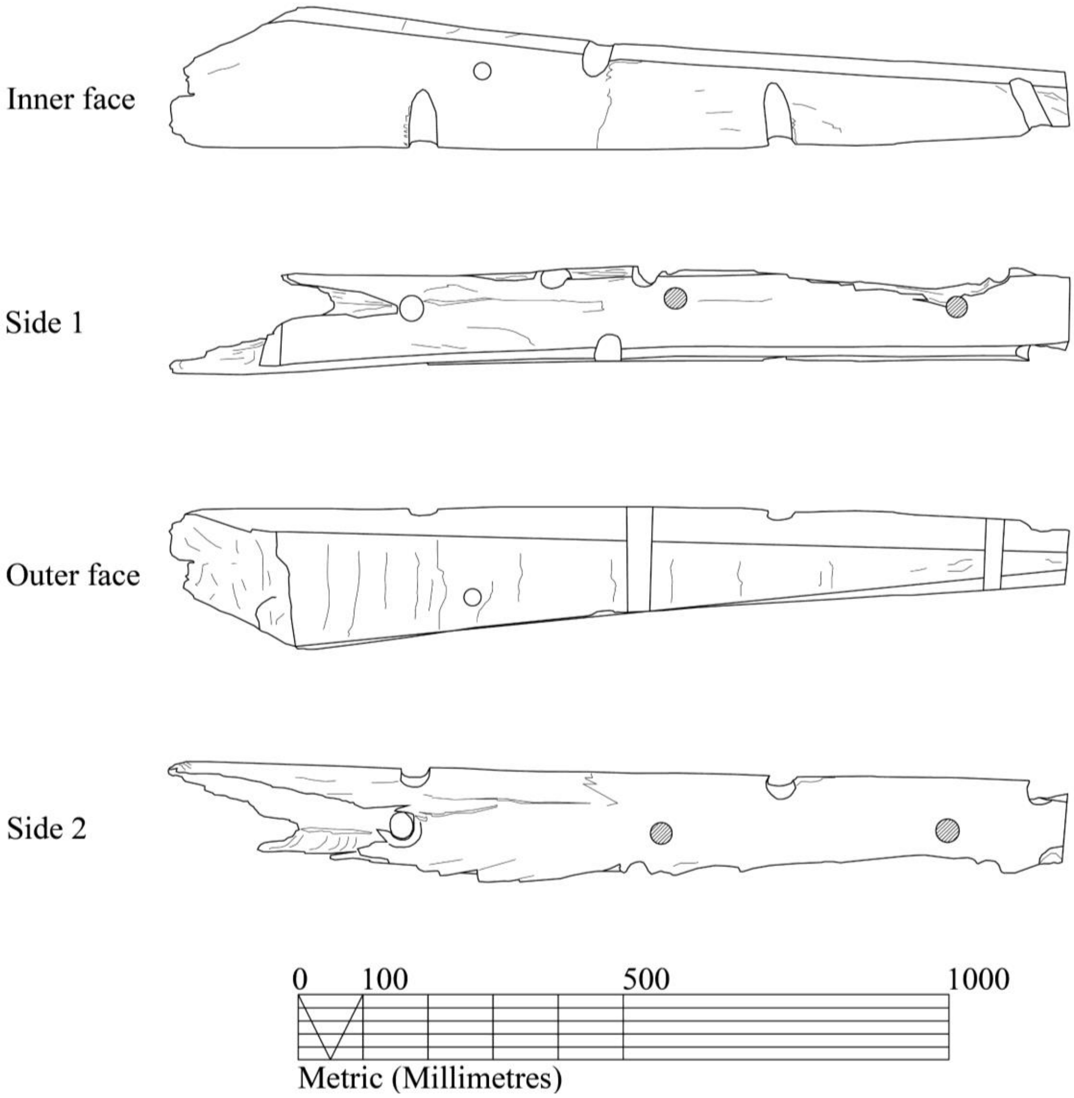

Figure 51. END_015 keel fragment drawing.

5.3.1.5 END_017 keel fragment

This timber fragment is identified as a possible part of the keel or keelson and as a possible continuation of END_006 (Figure 52). It appears to be an interior face of the same type of timber used as the keel. There are also notches cut into the inner face. The current condition of the timber is poor and therefore the timber joints are undiagnostic at the time of recording. The parent tree was halved during the conversion process. The preserved dimensions measure 1,598 mm in length, 327 mm moulded and 98 mm sided. Although the timber is probably part of the keel, there is no evidence of a rabbet line. The timber contains wooden and metal fasteners. Four extant treenails measured 41 mm in diameter; however, there is no evidence of wedges in the treenails. The magnet confirmed ferrous round fasteners and measured 31 mm in diameter. Due to the absence of original lengths, their extent was not measured. No evidence of surface coverings was present nor any sheathing tack impressions. The timber displayed both construction and tool marks, the construction marks shown in the form of possible scoring marks and divots, and tool marks were identified as possible saw marks. Two wood samples were collected for identification. These were T01 from the main timber fragment and T02 from a treenail.

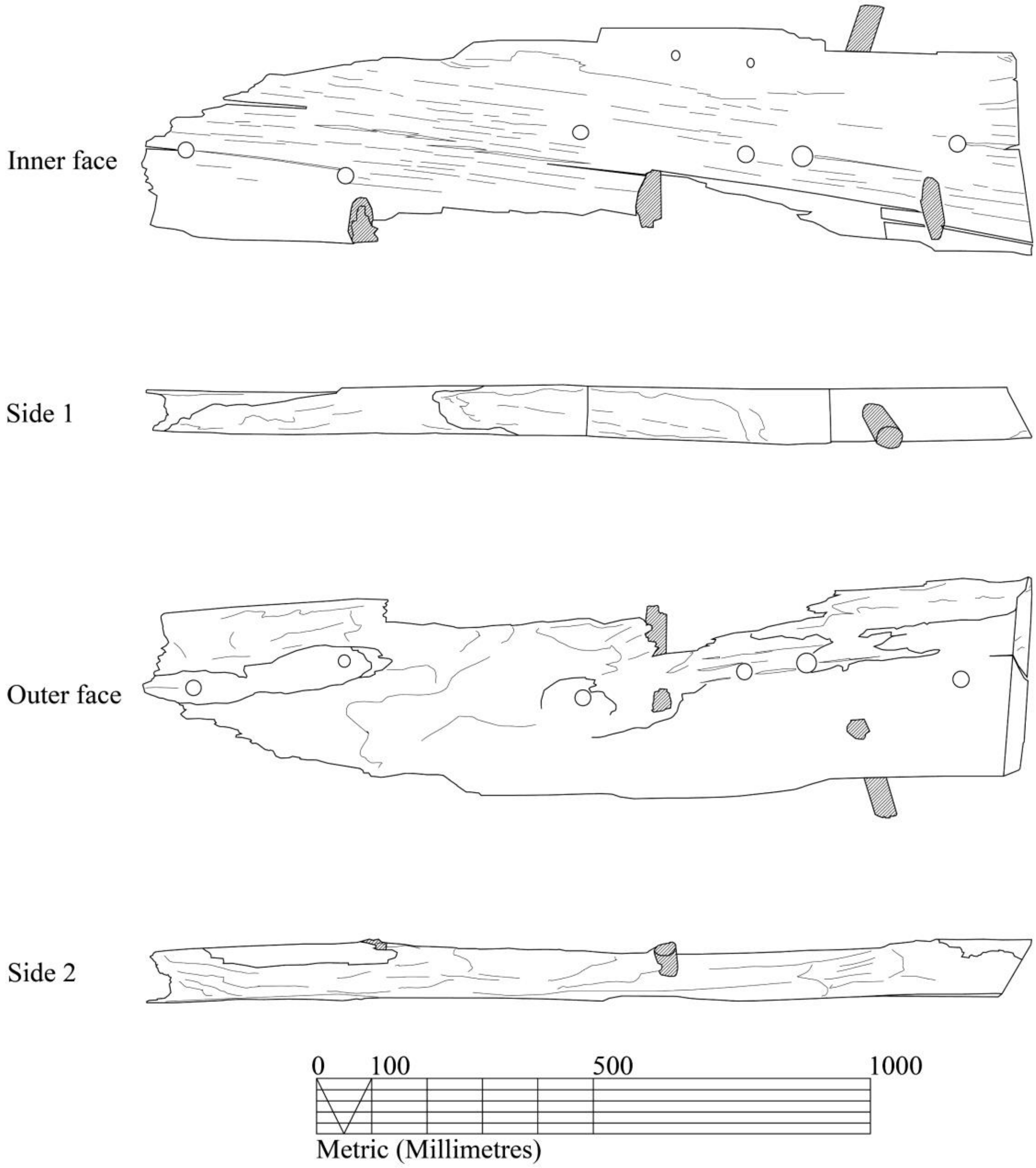

Figure 52. END_017 keel fragment drawing.

5.3.1.6 END_026 keel fragment

This keel fragment is associated with the scarf joint recorded on END_002 (Figure 53). It has been split from the original timber and displays evidence of modern salvage, where possible copper alloy keel bolts have been targeted and removed. The condition of the timber is poor due to the effects of modern salvage and natural weathering. When combined with the other associated timbers, the complete timber was converted whole from the original tree. The preserved dimensions of the timber measured 1,274 mm long by 188 mm moulded and 262 mm sided. A rabbet line appears to be a continuation from END_002. The rabbet measured 20 degrees and the back rabbet measured 72.1 degrees. From the inner rabbet line to the back rabbet line measured 89 mm and intersected the bottom recess. The bottom recess measured 77 mm from the outer rabbet line to the back rabbet line. All rabbet measurements were to broken edges and therefore, do not reflect the maximum measurements of the original dimensions. The timber has no extant remains of metal or timber fastenings, although there are holes that suggest fasteners were originally fixed in the timber. The treenail holes measured 41 mm in diameter and the metal fastener holes measured 38 mm in diameter. The suspected metal fastener holes have copper alloy residue around the perimeter and extend through the entire thickness of the timber. It is likely these holes match those recorded in END_007 that housed copper alloy keel bolts. The timber only contains wooden and copper fasteners. No extant surface coverings were on the timber, although there was evidence of a possible fibrous substance along the rabbet. Tack impressions, however, are visible on the outer face of the timber. These tack holes measured up to 5 mm by 7 mm in area on the surface and up to 27 mm in depth in the voids. No construction or tool marks were recorded on the timber. One wood sample was collected for identification. The fibre substance was not sampled because END_002 provided a better-preserved fibre sample for analysing caulking along the rabbet line.

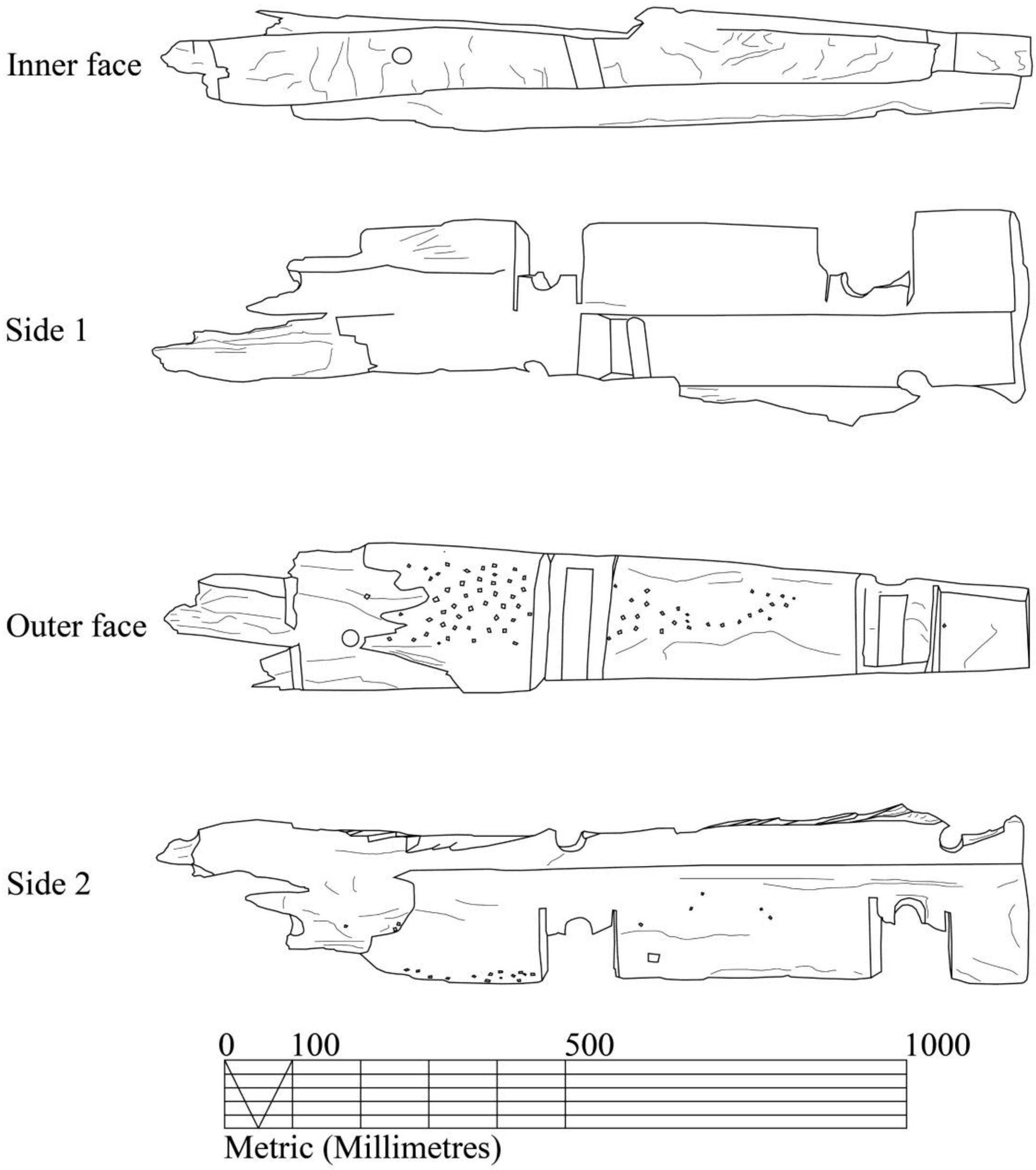

Figure 53. END_026 keel fragment drawing.

5.3.2 Futtocks

5.3.2.1 END_007 possible futtock

This timber was recorded as a possible futtock containing treenails as fasteners (Figure 54). The timber is broken and degraded at both ends and is in a poor state of preservation. The preserved dimensions of the timber measure 2,025 mm long by 295 mm moulded and 199 mm sided. The conversion of the original wood remains undetermined and timber joints are absent. There is evidence of 10 extant treenails and three empty treenail holes in this piece of timber due to the poor state of preservation. The extant treenails measured 38 mm in diameter and do not provide evidence for wedges. No metal was detected on the timber and there was no evidence of surface coverings. No construction or tool marks were visible on the different faces of the timber. Overall, due to the condition of the timber it was difficult to determine or identify diagnostic features. One wood sample was collected for identification.

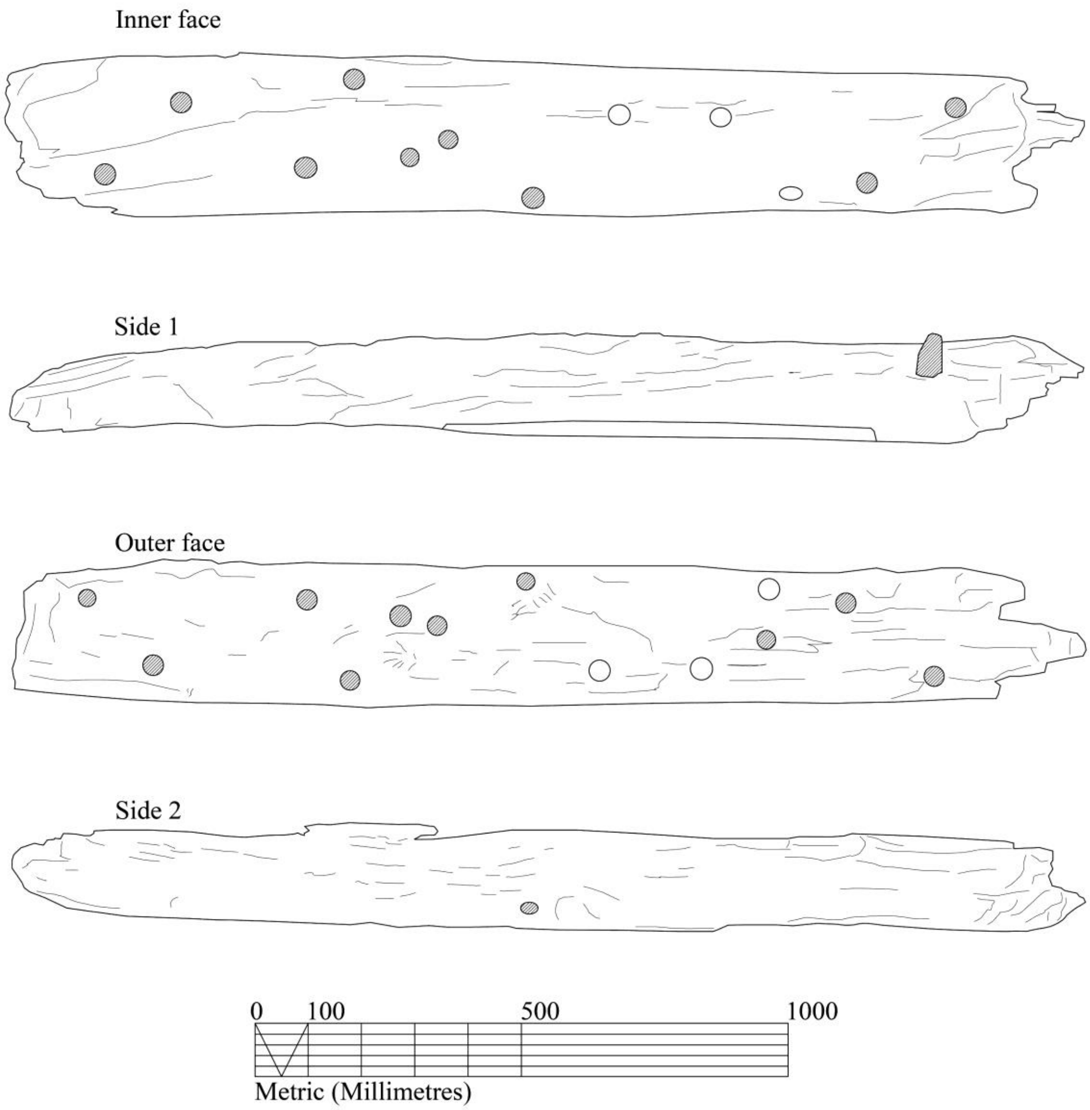

Figure 54. END_007 futtock drawing.

5.3.2.2 END_013 possible futtock

This timber is identified as a possible futtock fragment (Figure 55). The condition of the timber is poor and has very worn edges and faces. As a result, the conversion of the timber could not be determined. Both ends were in poor condition, however, one end is bevelled and indicates it might have been a possible scarf joint. The preserved timber measures 1,188 mm long, 132 mm sided and a maximum moulded dimension measures 192 mm. Three treenails measured 38 mm in diameter. No wedges were present; however, the driving ends were preserved and exited through the outer face. A round fastener measuring 25 mm in diameter is present. There was no evidence of surface coverings attached to the timber and the inspection of the timber did not record any construction or tool marks. A wood sample was collected for identification.

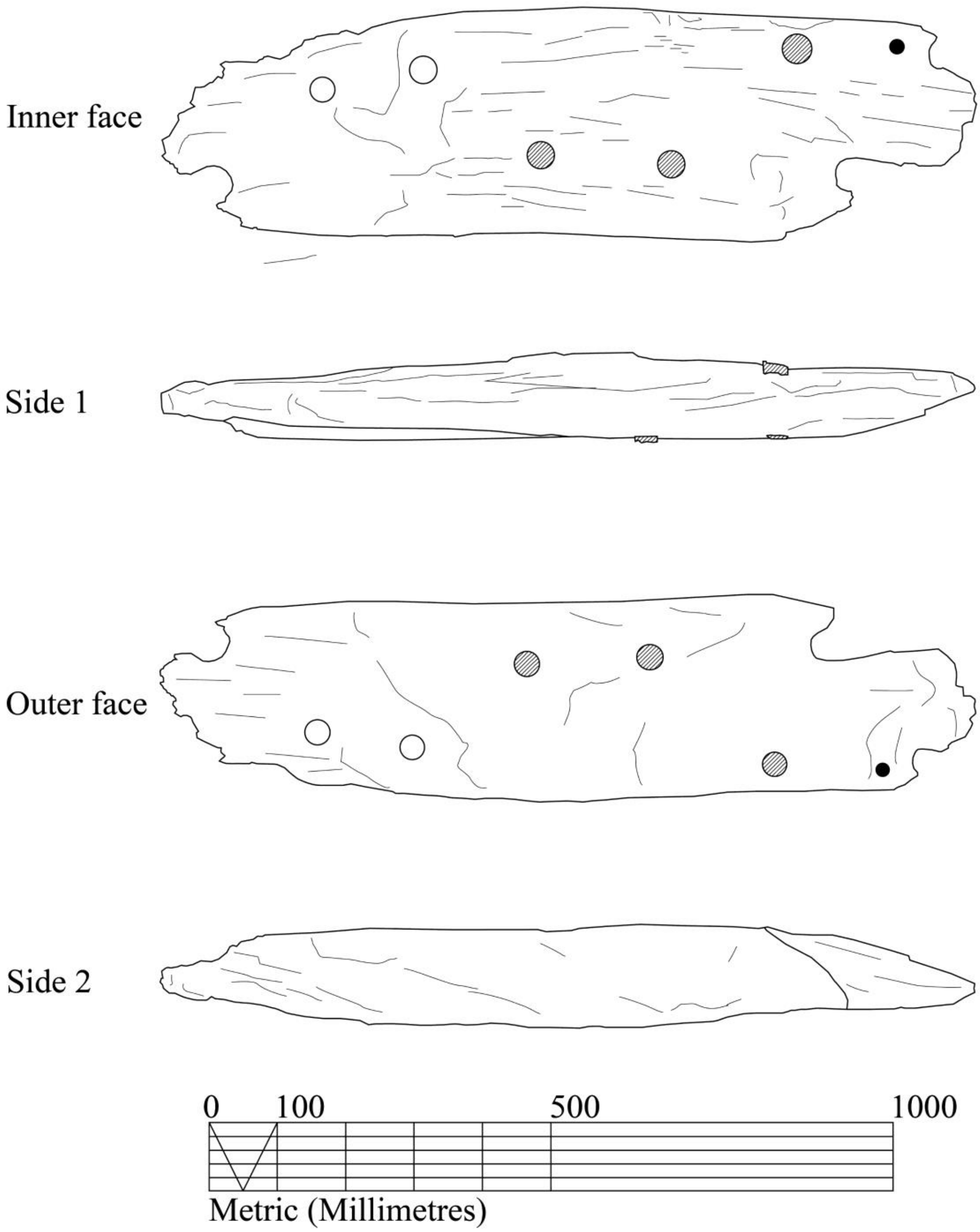

Figure 55. END_013 futtock drawing.

5.3.3 Garboard strake

5.3.3.1 END_019 garboard strake

This strake is in a fair state of preservation. The timber was converted as a half from the original tree with no timber joints identified. The timber has a preserved length of 2,945 mm. The moulded face measured a maximum 291 mm by 114 mm sided. Seven extant treenails measured 39 mm in diameter (Figure 56). Their lengths were not measured because both ends were degraded. It is possible square wedges may be present in the treenails although they were difficult to identify, if any, due to the condition and cracking of the treenails. The possible square wedges, however, measured 29 mm by 39 mm in area and their depth could not be measured. No ferrous metal fasteners were detected. A visible organic surface covering in the form of possible pitch exists between the timber and outer sheathing. Square sheathing tacks as impressions in the timber measured 3 mm square. No construction marks were recorded, however, tool marks resembled possible saw marks. These are located on inner face where the timber has been converted. Wood and fibre samples were taken for identification.

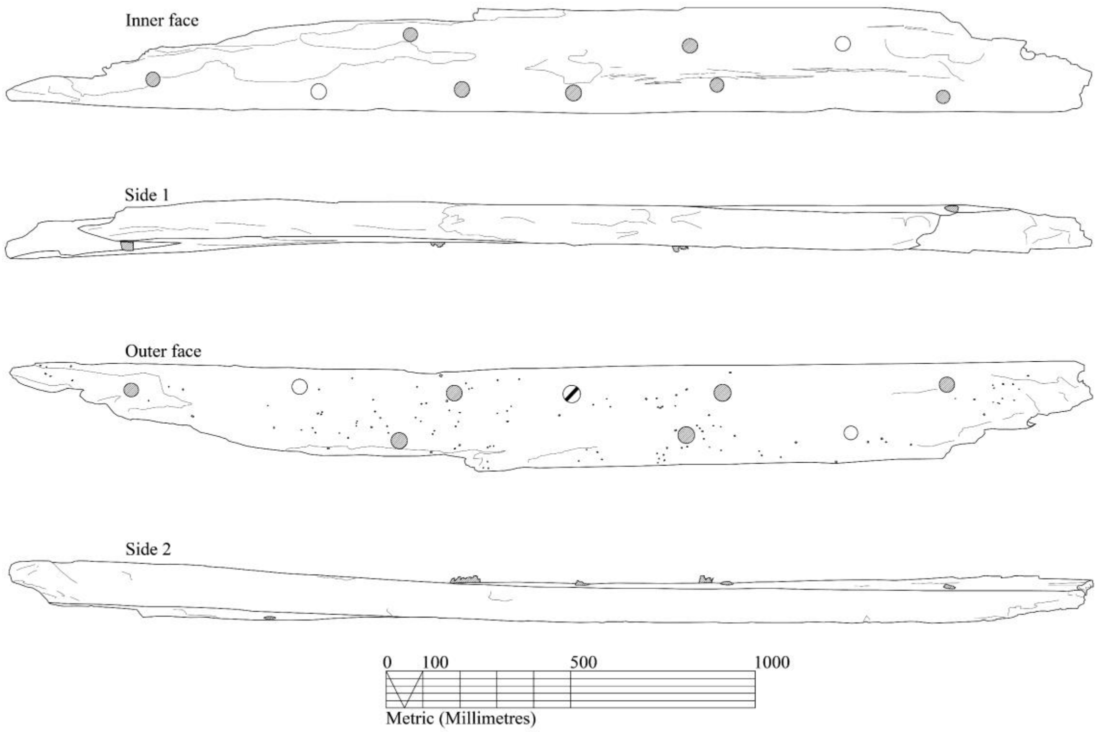

Figure 56. END_019 garboard strake drawing.

5.3.4 Outer planking

5.3.4.1 END_010 outer hull planking

The plank is in a fair state of preservation but has a degraded end. Due to the degradation of the timber, no joints are visible. The end grain indicates the conversion of the original tree has been halved. The preserved length measured 1,942 mm (Figure 57). The maximum moulded face measured 261 mm by a maximum 101 mm thick. Treenails and a metal fastener exist in the timber. In four treenail holes, two treenails measured 40 mm in diameter, although no wedges were present due to the degraded treenail ends. Only one square alloy fastener was recorded and measured 3 mm by 6 mm in area at the surface of the timber. The head diameter could not be measured as it no longer exists. Construction marks were not identified but tool marks displayed uniformed saw marks. They were straight and closely spaced measuring 3 mm apart. Another clue to suggest it may be a plank is the form of the timber. It appears to be curved as to fit the curvature of the hull. Although, it is equally possible the curve may have been created from incorrect storage and non-conservation treatment.

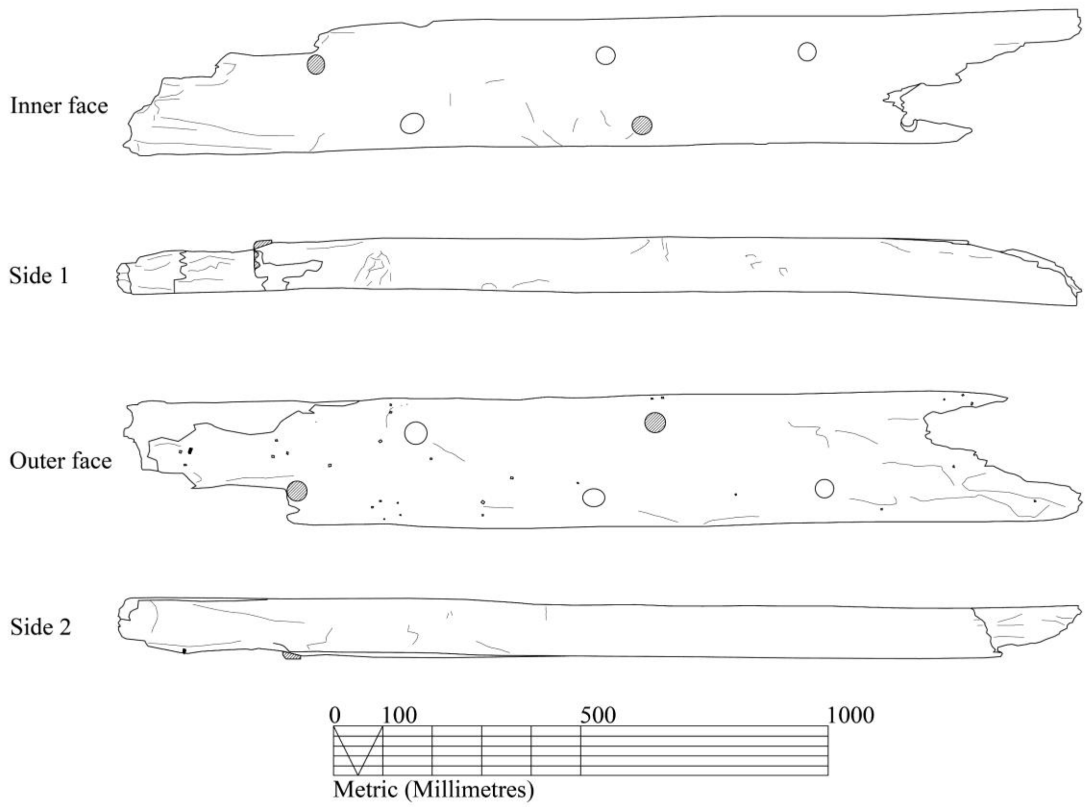

Figure 57. END_010 outer hull plank fragment drawing.

Surface coverings on side 1 appear to be a mixture of fibre mixed with a resinous substance and applied to both longitudinal faces. There is also an orange fibrous material on the possible inner face of the plank. In addition to this, there are impressions left behind from square tacks on the outer face. The sizes of these holes varied and measure between 2 mm and 6 mm square. Wood and fibre samples were collected for further analysis.

5.3.4.2 END_011 outer hull planking

This timber is badly degraded on two faces and has broken or marine worm-eaten ends. Through the milling process, the timber was converted tangentially. The timber measured preserved dimensions of 1,548 mm long, 160 mm moulded and a maximum thickness of 105 mm (Figure 58). One extant treenail located in the timber measured 38 mm in diameter. There are no extant treenail wedges. The magnet did not detect any ferrous metal, but square fasteners of a possible copper alloy exist in the timber. These alloy nails measured 3 mm by 3.5 mm square. The length of the shank could not be measured as the heads no longer exist. There is no evidence of surface coverings. There are no construction marks, although possible saw marks are recorded as tool markings. The saw marks are spaced approximately 5 mm apart. The cuts were straight and uniform in positioning. A wood sample was collected for identification.

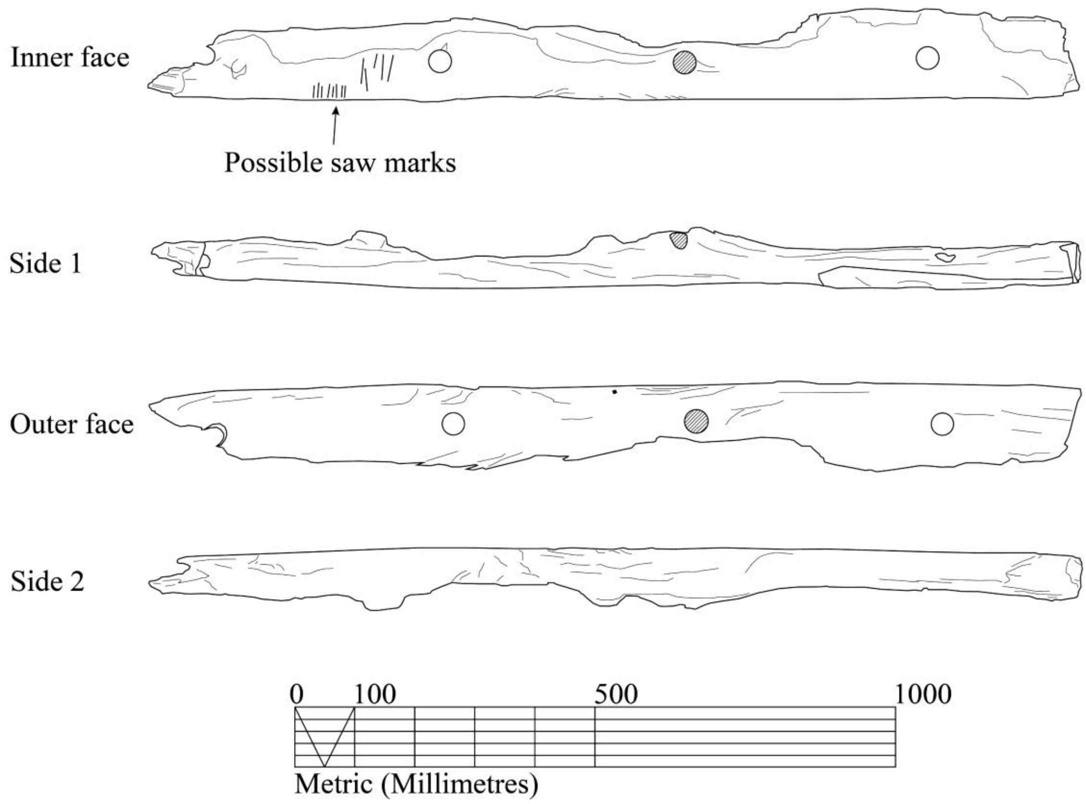

Figure 58. END_011 outer hull plank fragment drawing.

5.3.4.3 END_012 outer hull planking

This possible plank containing fasteners is in poor condition as all the faces, except the inner face and ends are heavily degraded. As a result, the timber conversion was not identified. The preserved dimensions measured 1,528 mm long, 308 mm moulded and 105 mm thick (Figure 59). One extant treenail measured 38 mm in diameter with no wedge. The treenail, however, still had the driving end preserved which extends past the inner face. Ferrous fasteners were detected lodged in the timber. The ferrous fasteners are square in shape and measured 18 mm by 19 mm at their exposed ends. The lengths of these could not be measured. Copper alloy round fasteners are also present in the timber and measured 18 mm in diameter. The existing lengths of the fasteners could not be measured. No construction or tool marks were visible on the timber faces. A wood sample from the timber fragment was taken for identification.

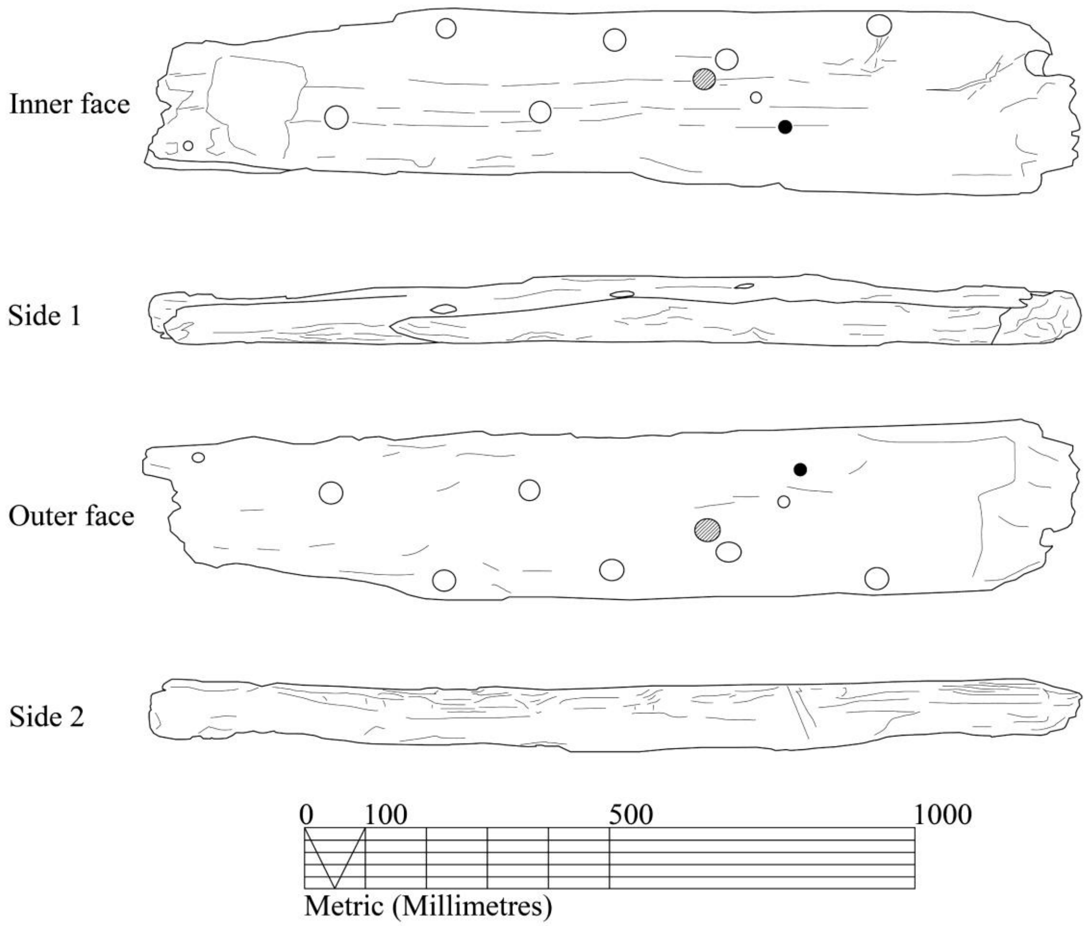

Figure 59. END_012 outer hull plank fragment drawing.

5.3.4.4 END_014 outer hull planking

This possible outer plank is in a poor state of preservation. The plank was converted tangentially with possible butt joints at each end. Due to the degradation, however, the timber joints were not confirmed. The timber's preserved length measured 1,189 mm while the maximum moulded dimension measured 215 mm and the maximum thickness measured 105 mm (Figure 60). Two extant treenails, one with a wedge, measured 39 mm in diameter. The wedge measured the diameter of the treenail by 3 mm thick. The magnet did not detect any ferrous metal and no surface coverings exist. There are small square holes, however, on the outer face of the timber and it is possible this resembles sheathing tacks. These holes measured 3 mm square and up to 7 mm in depth. No construction marks were recorded. Tool marks in the form of small chisel marks on side 1 measured 9 mm in length by 3 mm wide and tapered to a maximum depth of 2 mm towards one end. A wood sample was collected for identification.

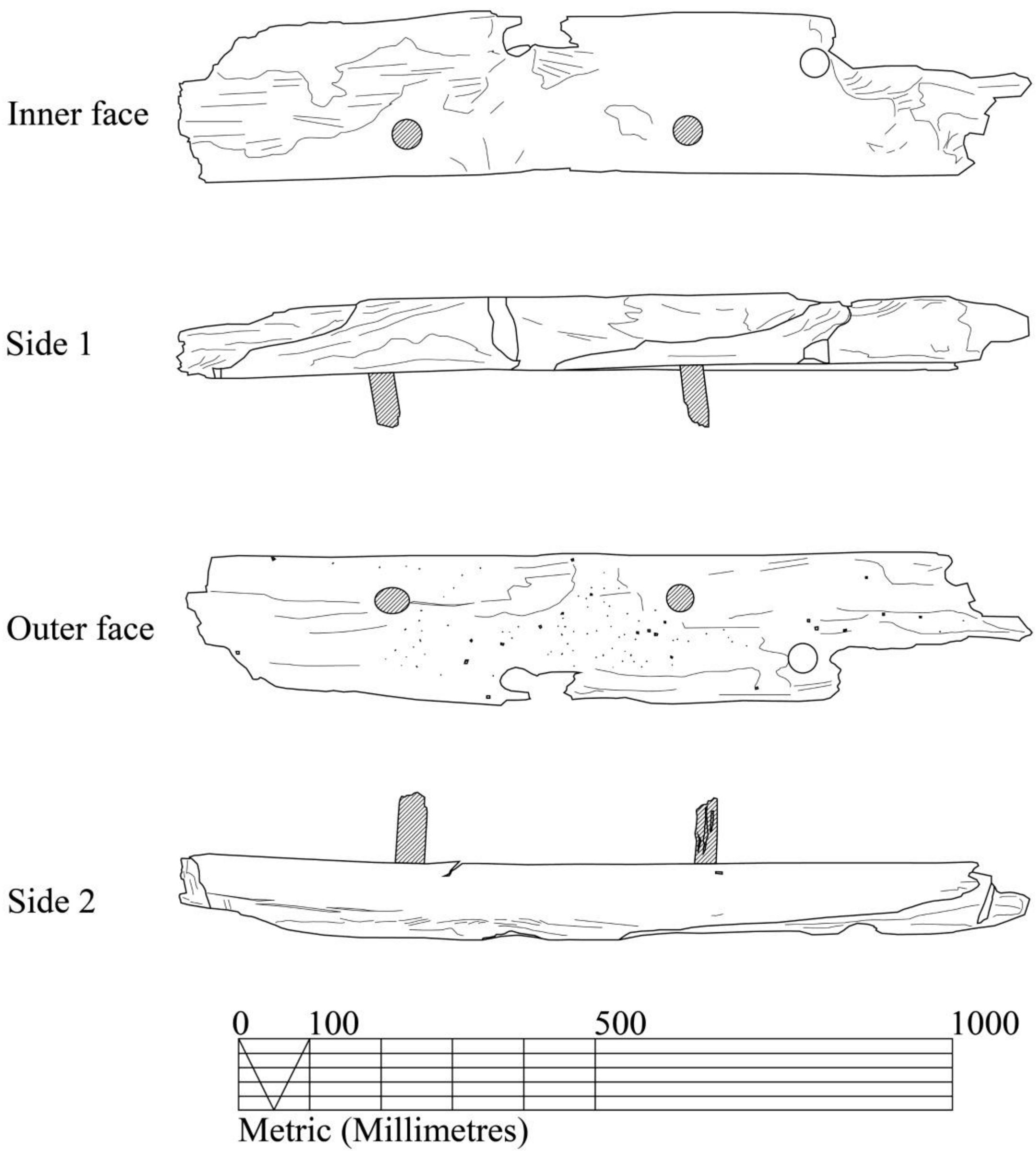

Figure 60. END_014 outer hull plank fragment drawing.

5.3.4.5 END_016 outer hull planking

This timber fragment is rectangular in cross-section with one end broken and the opposite end square cut indicating a possible butt joint. There are saw marks which possibly indicates modern sawing activity (Figure 61). The timber's preservation is fair, and the conversion of the timber is halved from the original log. The timber measured a preserved length of 1,562 mm, a maximum moulded measurement of 234 mm and a preserved thickness measurement of 90 mm. Nine extant treenails measured 41 mm in diameter. No wedges were present in the treenails due to their degraded ends. Copper alloy round fasteners measured 26 mm in diameter. No ferrous metal was detected; however, other metal fasteners were measured at 5 mm by 7 mm in area on their exposed surface. Their lengths could not be measured. No extant surface coverings exist on the timber faces, although square impressions of tack holes survive on the outer face. These holes measured 3 mm square and up to 11 mm in depth. Construction marks in the form of possible scoring marks were evident next to the end that is square cut, whereas no tool marks were identified. A wood sample was collected for identification.

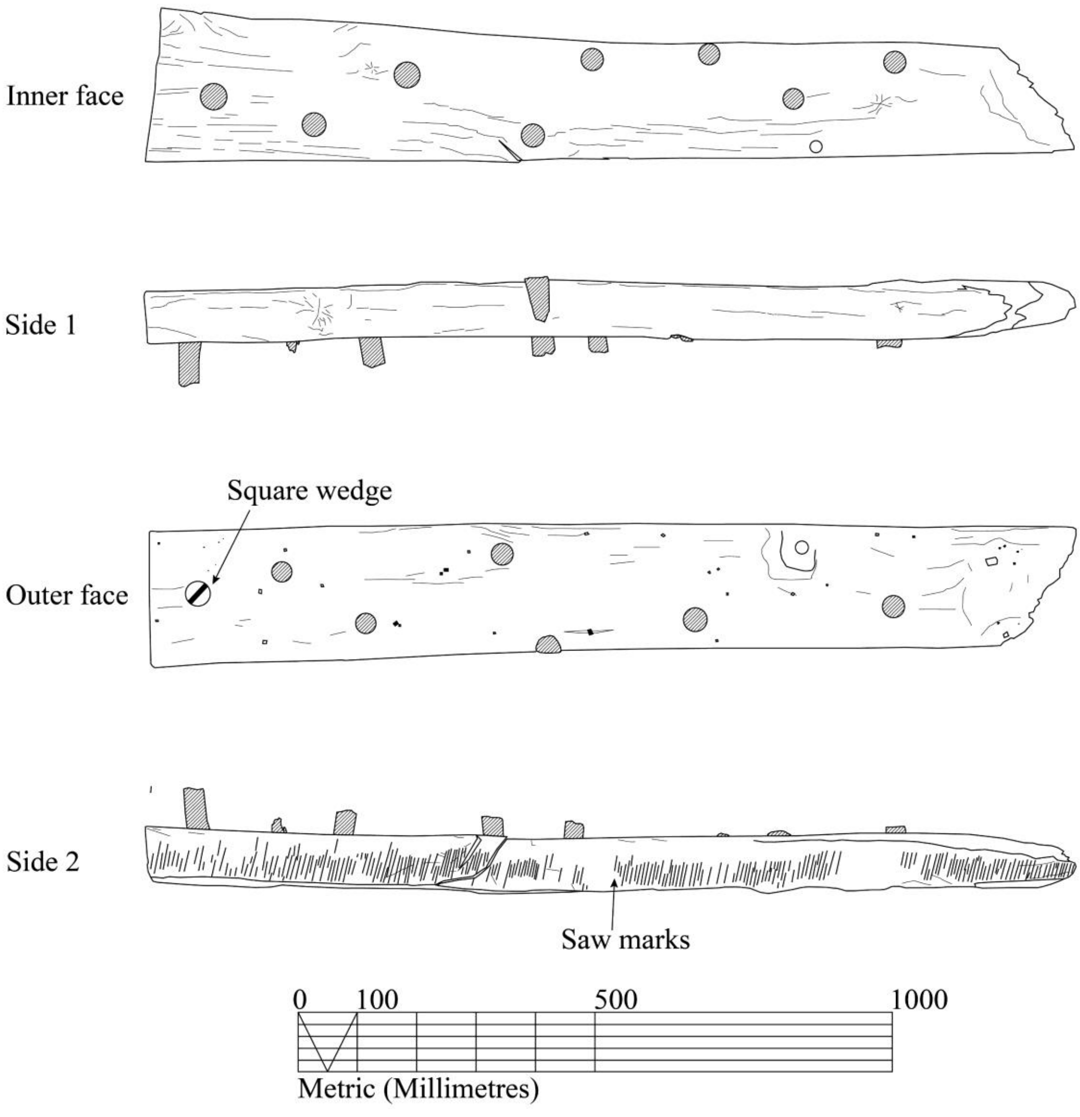

Figure 61. END_016 outer hull plank fragment drawing.

5.3.4.6 END_018 outer hull planking

This possible outer hull plank is currently preserved in a fair condition with both ends degraded and broken. The conversion could not be identified and there are no diagnostic joint features visible. The timber measured a preserved length of 3,284 mm by a maximum moulded dimension of 307 mm and 91 mm thick (Figure 62). Seven treenails are evident and each measured 37 mm in diameter. A total of 18 treenail locations were recorded which includes the nine extant treenails. Square wedges exist in two treenails visible on the outer face. No ferrous metal was detected and there was no extant evidence of surface coverings. The recording of impressions suggests sheathing tacks once existed in the outer face. A possible graving piece at one end of the timber was identified as evidence of construction markings. The timber itself does display several imperfections and it is possible the graving piece removed a pre-existing knot. The graving piece area measured 131 mm in length by 20 mm deep. A wood sample was collected for identification.

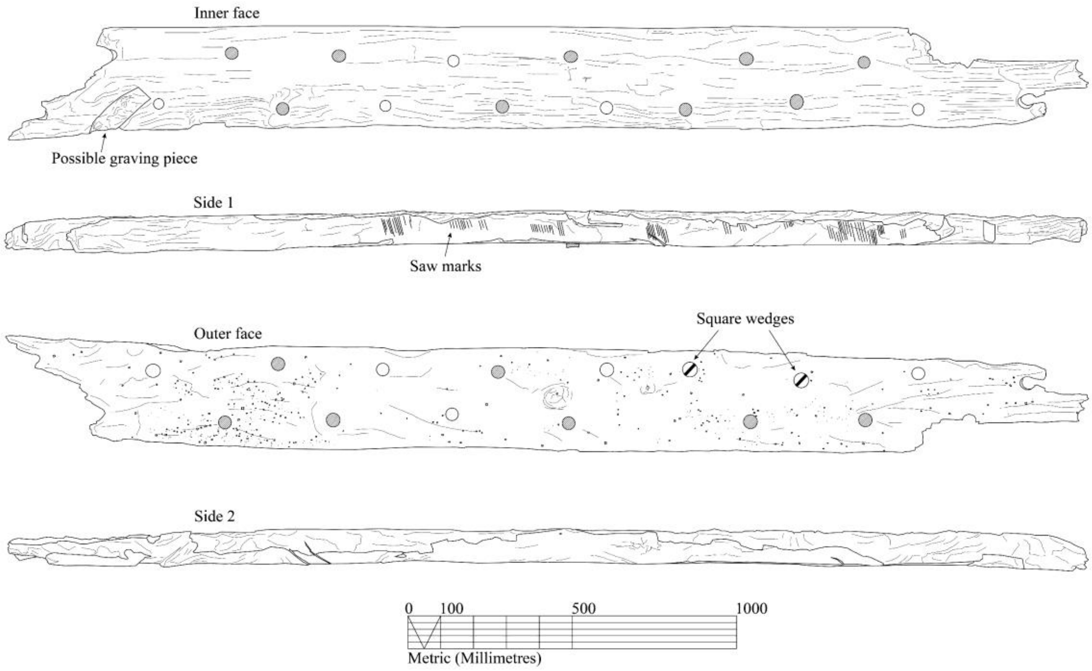

Figure 62. END_018 outer hull plank fragment drawing.

5.3.4.7 END_020 outer hull planking

This outer plank's fragment condition is poor. Therefore, the timber and any evidence of joints could not be determined. The preserved length measured 2,122 mm with a maximum original moulded measurement of 320 mm and a maximum 100 mm thick (Figure 63). One recorded extant treenail measured 38 mm in diameter and there was no evidence of it having a wedge. A total of 11 treenail holes exist in the timber, including the extant treenail. A copper alloy fastener embedded in the timber measured 6 mm by 8 mm at the top of the shank. The magnet did not detect any ferrous metal and there were no visible remains of organic coverings. There were, however, impressions of square sheathing tack holes reaching a maximum depth in the timber of 5 mm. Furthermore, the timber displayed no visible evidence of construction markings, although there are possible hammer tool marks. One wood sample was collected for identification.

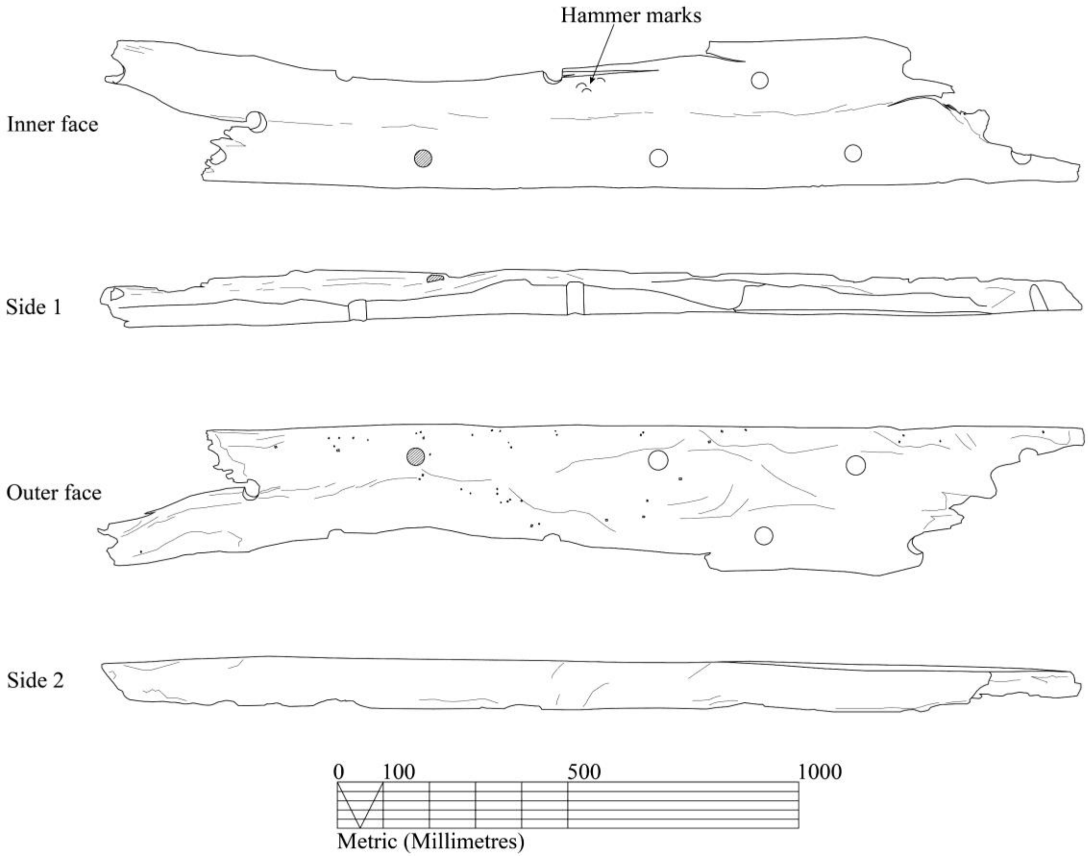

Figure 63. END_020 outer hull plank fragment drawing.

5.3.4.8 END_021 outer hull planking

This outer plank's condition is fair with both ends broken and degraded. The timber conversion is halved from the original tree and no diagnostic joint features exist. The timber measured a preserved length of 2,656 mm (Figure 64). The moulded dimension measured a maximum 260 mm and a maximum 98 mm thick. Five extant treenails measured 41 mm in diameter with a total of 15 locations for treenails positioned in the timber. Square wedges are present in the treenails and measured 30 mm by 25 mm in area. The magnet did not detect any ferrous metal. There were no extant surface coverings, however, there were square sheathing tack holes on the outer face. These holes measured approximately 3 mm by 3 mm and their depths ranged between 1 mm and 6 mm. No construction marks were visible, although tool marks in the form of possible saw marks were recorded. The arcing of the cuts suggests a circular saw. A wood sample was collected for identification. The curator did not permit sampling the treenails and their wedges.

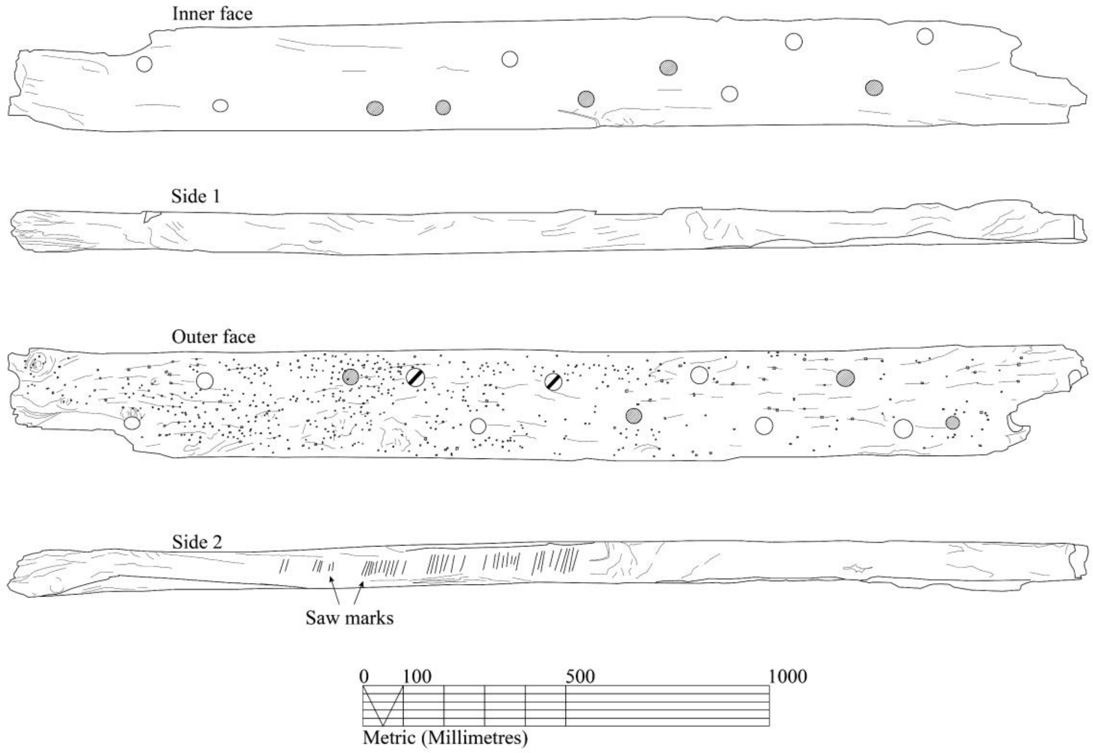

Figure 64. END_021 outer hull plank fragment drawing.

5.3.4.9 END_022 outer hull planking

This possible outer plank’s condition is poor with both ends broken and degraded. Two opposite faces are also degraded. No joint features were identified. The preserved dimensions of the timber measured 676 mm long by 137 mm moulded and 102 mm thick (Figure 65). No extant fasteners were present, although there were three treenail holes. These holes measured 40 mm in diameter. No ferrous metal remains in the timber. No visible remains of surface coverings exist on the timber, although there are square sheathing tack impressions left in the suspected outer timber surface. The impressions measured 3 mm by 3mm in area and up to 12 mm in depth. There were no construction or tool marks identified on the timber. One wood sample was collected for identification.

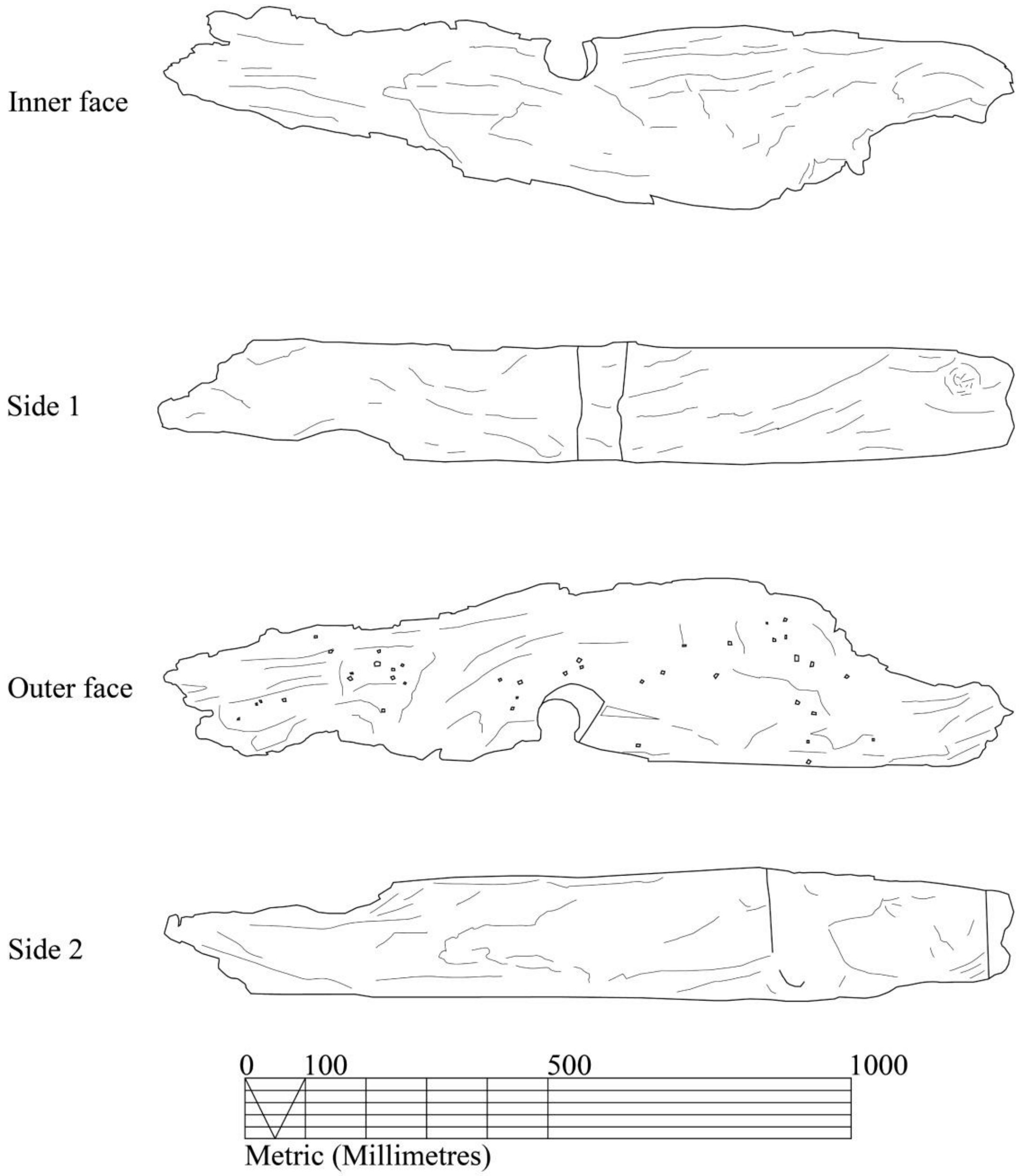

Figure 65. END_022 outer hull plank fragment drawing.

5.3.4.10 END_023 outer hull planking

The condition of this outer plank is fair but it has broken and degraded ends. The timber was converted tangentially from the parent tree. A possible butt joint was identified at one end of the timber, but it is not certain if it is original or contemporary. It is probably original, as the cut is straight and is not irrational like the other possible saw cuts associated with salvage activity seen on the other timbers. The preserved length measured 1,396 mm by a preserved moulded measurement of 224 mm. The thickness measured a maximum 98 mm (Figure 66). Evidence of nine treenail holes are present in the timber, but no treenails exist for measuring. The magnet did not detect any ferrous metal. No extant evidence of surface coverings exist for recording. Impressions of square tack holes are visible on the outer face and measure 3 mm by 4 mm in area. No construction marks were recorded. The tool marks recorded as saw marks appeared to be angled and measured 6 mm apart. The timber was sampled for wood identification.

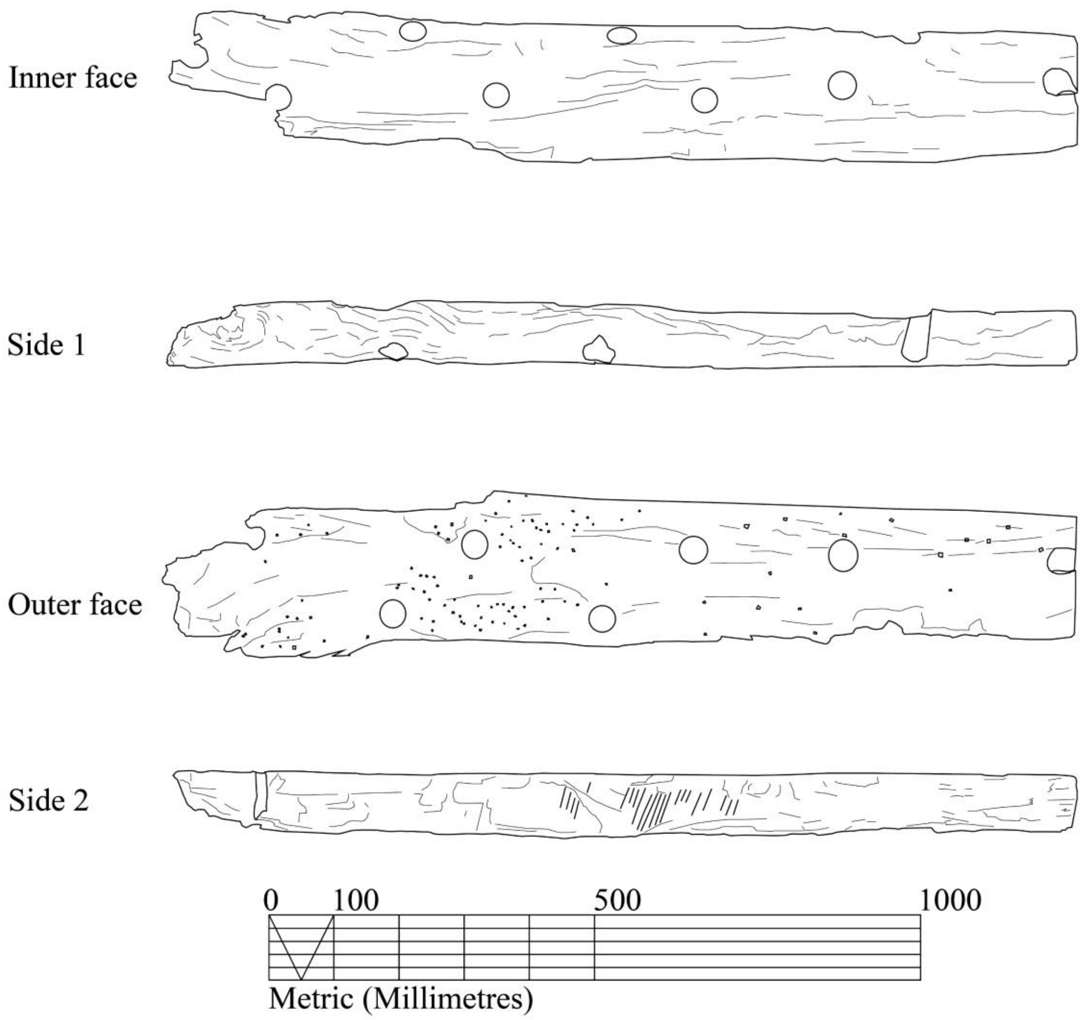

Figure 66. END_023 outer hull plank fragment drawing.

5.3.4.11 END_024 outer hull planking

This exterior hull plank's condition is fair with both ends broken and degraded. The grain, however, is visible and shows it has been converted as a half from the parent tree. There is also evidence of a possible butt joint on one end, but the degradation makes it difficult to distinguish if it is original or modern. The preserved length of the timber measured 2,354 mm (Figure 67). Whereas the maximum moulded dimension measured 273 mm by a maximum 98 mm thick. A total of 11 locations for treenails are present in the timber with six extant treenails. The diameters of the larger treenails measured 40 mm. There is also one smaller treenail that measured 25 mm in diameter. This treenail contained a flat wedge and measured 4.5 mm thick by the diameter of the treenail. The magnet did not detect any ferrous metal. No organic or metal sheathing surface coverings were present on the timber. Rectangular tack impressions measured approximately 7 mm by 3 mm across and up to 21 mm in depth. No construction marks were visible; however, there were tool marks in the form of possible saw marks. They appeared to be arcing and were uniformly spaced 7 mm apart on side 2. One wood sample was collected for identification.

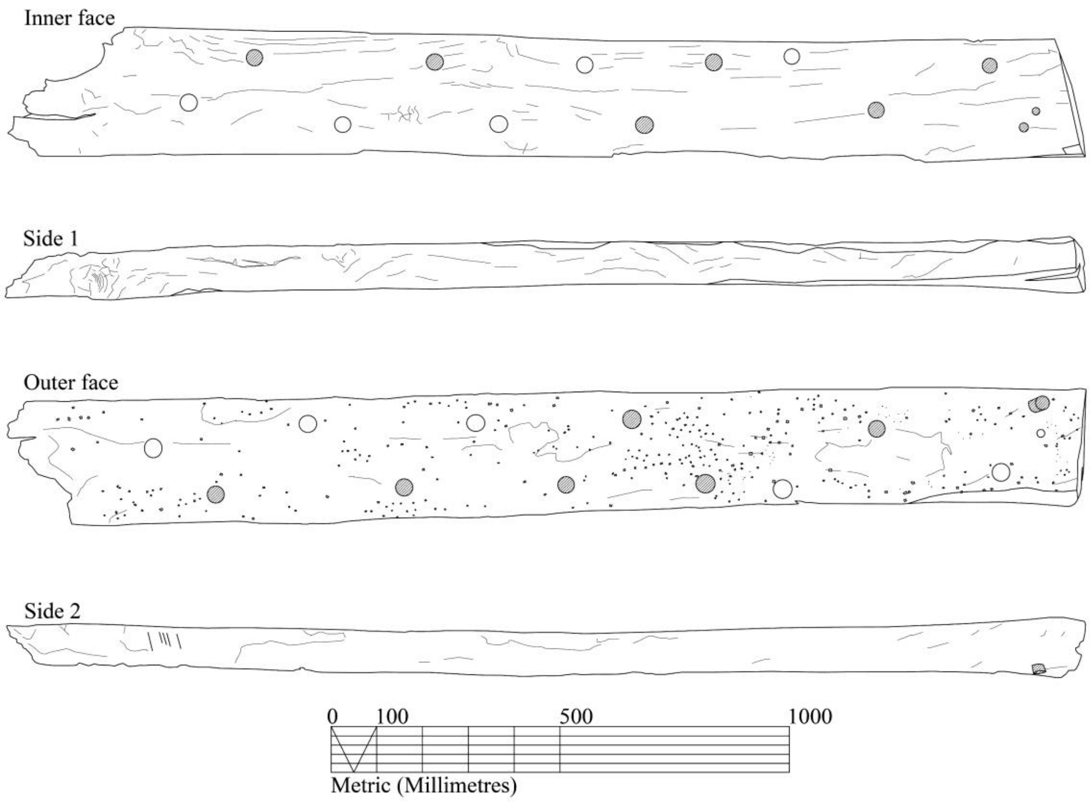

Figure 67. END_024 outer hull plank fragment drawing.

5.3.4.12 END_025 outer hull planking

This outer plank is heavily degraded on both ends with limited preserved faces. The condition of the timber is poor and as a result the conversion of the original tree could not be determined. Furthermore, any use of timber joints could not be distinguished. The preserved length measured 1,252 mm by a maximum 276 mm moulded and 98 mm thick (Figure 68). Five treenail holes are present in the timber with one extant treenail that measured 41 mm in diameter. There were no wedges. The application of the magnet did not detect any ferrous metal. There were also no remaining extant surface coverings. On the outer face, however, tack impressions measured up to 5 mm by 6 mm in area and to a maximum depth of 27 mm. No construction marks remained on the timber, although tool marks were recorded on the little area of original surface. These were possible saw marks measuring 6 mm apart and indicated they were produced by a circular blade. One wood sample was collected for identification.

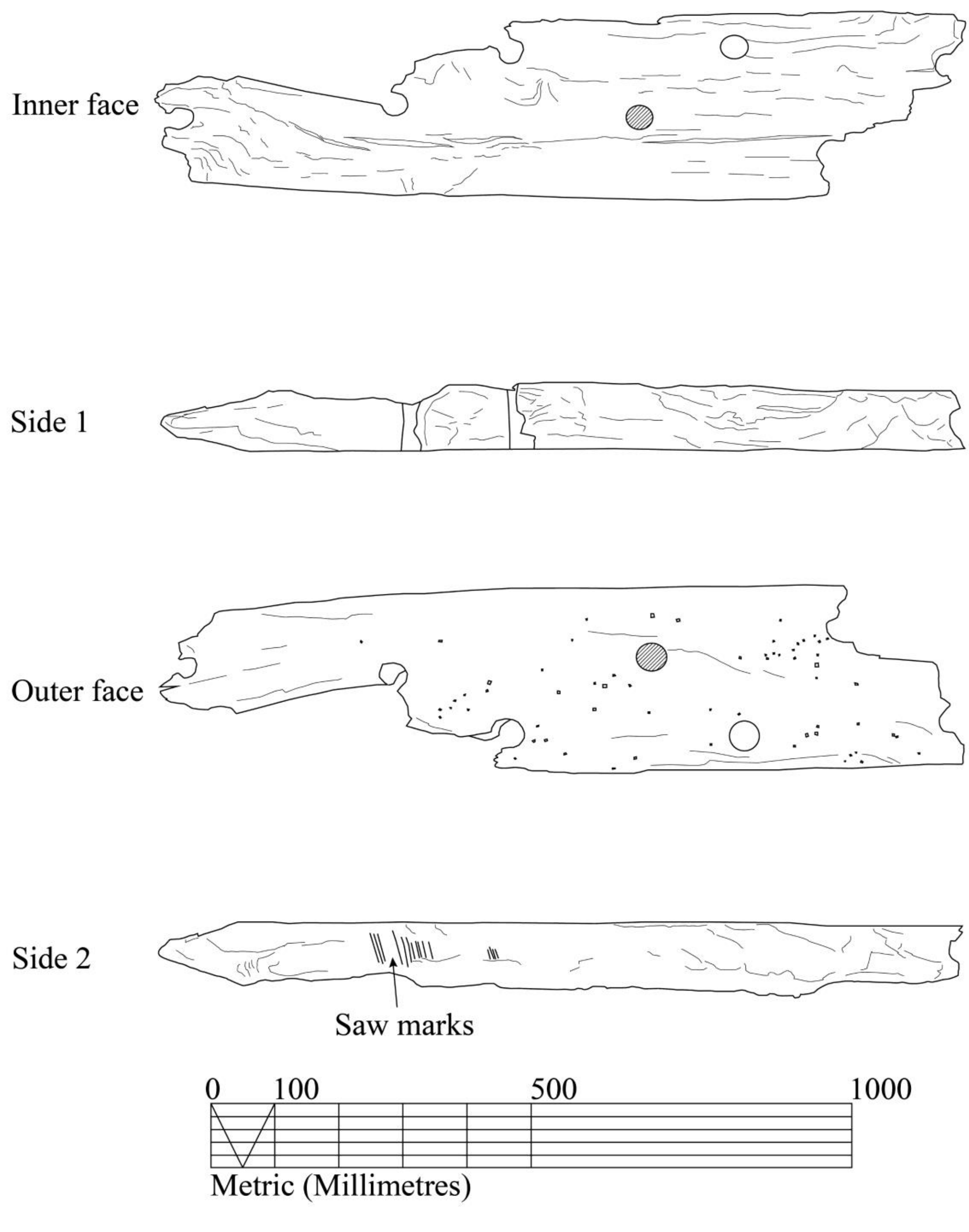

Figure 68. END_025 outer hull plank fragment drawing.

5.3.4.13 END_028 outer hull planking

This outer plank's condition is poor with broken and degraded ends. Timber joints at each end could not be determined. The wood grain is clear, although fibrous and shows a tangential conversion from the original tree. The plank measured a preserved length of 760 mm, moulded 146 mm and 63 mm thick (Figure 69). One extant treenail in the timber measured 30 mm in diameter. It also displayed a wedge in one end and measured 10 mm wide by the diameter of the treenail. The magnet did not detect any ferrous metal and no extant surface coverings were visible. Copper alloy sheathing tacks, however, were visible in the timber. They are square shanked with 8 mm diameter heads. Notably, the head's diameters are smaller than others recorded within the same *Endeavour* timber collection. No construction or tool marks were present on the timber. At the time of recording it was thought this piece is unlikely to be associated with *Endeavour*, however, it could also reflect a repair. One wood sample was collected for identification.

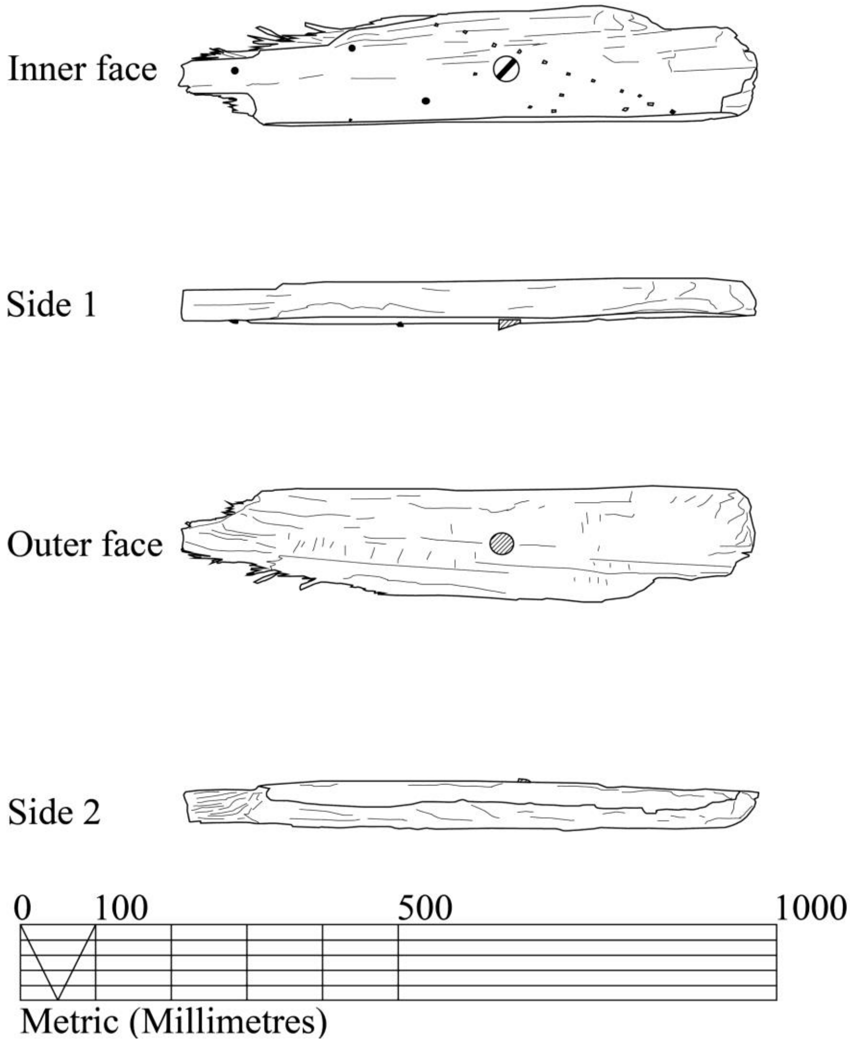

Figure 69. END_028 outer hull plank fragment drawing.

5.3.5 Sacrificial timber sheathing

5.3.5.1 END_004 Sacrificial timber sheathing

This assemblage consisted of two outer timber planks with sheets of metal sheathing attached (Figure 70). The condition and fragility of the timber meant that the recording was only conducted on the face that was visible within its purpose-built storage container. Museum staff did not permit the timber's removal from its packing. Therefore, both the planks and metal sheathing were recorded as one feature item. The condition of the timber is in a poor state of preservation and the conversion of the wood could not be determined due to the packing of the crate. The ends of both planks appeared to be broken except for one end on the longest existing plank which showed a possible vertical scarf joint. The longest plank measured a preserved length of 3,285 mm by 280 mm moulded and 31 mm thick. No ferrous metal was positively identified; however, square fastener holes exist within the timber. These holes measured 7 mm by 6 mm. No construction or tool marks were identified on the timbers.

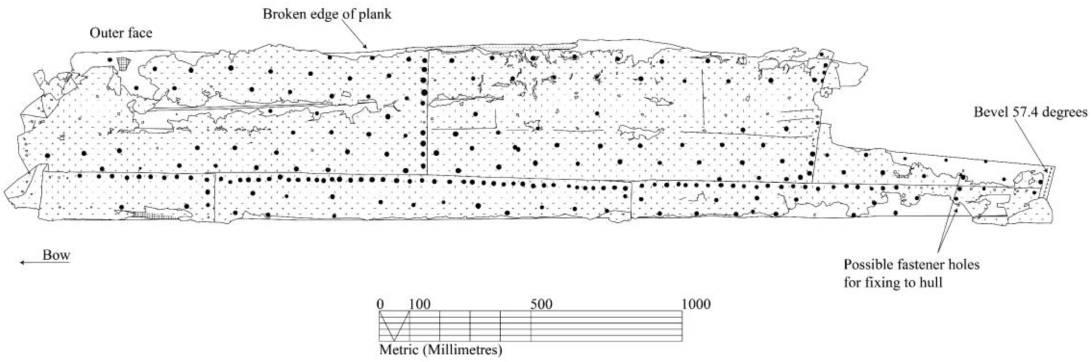

Figure 70. END_004 sacrificial timber and metal sheathing drawing.

The timber is covered with metal and organic surface coverings. The length of an individual metal sheet measured approximately 1,401 mm in length with a thickness of 0.9 mm. Each sheet overlapped with the other by a maximum of 40 mm in width. Sheathing tacks are visible across the entire fragment and provided data relating to patterning as well as individual tack dimensions. A sample of tacks displaying their overall lengths measured up to 34 mm in length with head diameters measuring between 11 mm and 15 mm. Distances between tacks measured approximately 35 mm along the vertical overlap edges. The distances between tacks along the horizontal edges did not measure uniformly and ranged between 28 mm and 120 mm apart. The maximum width of the sheets could not be measured due to not being complete. No maker's marks were visible but could still be present on the face not visible at the time of recording. The organic coverings appeared to be fibre woven matting between the metal sheathing and timber planks. No wood samples were collected, due to the condition of the timber planks. Metal and fibre samples were collected for identification and analysis.

5.3.5.2 END_005 (-A, -B and -C) Sacrificial timber sheathing

Three small fragmentary pieces of timber are packaged alongside END_004 in the same storage crate. The origin of the fragments is not known although it is believed by museum staff that they have fallen off END_004 at one point in time as they are all packed together. It is probable these timber fragments are pieces of sacrificial sheathing because they are similar to END_004 and contain evidence of metal sheathing. The condition of the fragments is rated as poor as none showed original faces or edges and were deemed too fragile to handle. The longest fragment was labelled with suffix 'A', through to the shortest length, with suffix 'C'. These timbers were photographed but not drawn. Fragment A measured a preserved length of 615 mm, 21 mm moulded and 21 mm thick. No other fastenings were detected by the magnet. No construction or tool marks were visible on the timbers.

The extant metal sheathing measured a length of 230 mm by 55 mm wide. The thickness of the sheathing measured 0.8 mm making it comparable to the sheathing recorded on END_004. The sheathing tacks have square shanks and the heads measured c.11 mm in diameter. The lengths of the shanks were not measured because they are unexposed. No maker's stamps were visible. A wood sample was collected for identification.

5.3.5.3 END_029 Sacrificial timber sheathing

This small fragment of sacrificial timber sheathing is probably cut from the ship as a modern souvenir (Figure 71). The condition of the timber is in a fair state of preservation, although no original timber joints are evident. The ends, however, show a tangential conversion. The preserved length measured 201 mm by a preserved moulded measurement of 232 mm. The thickness dimension was preserved and measured a maximum 24 mm. A square metal nail was tacked onto the timber, possibly by the person who salvaged the materials. It is probable then that this fastener was collected during souveniring and came from another part of the ship. The middle of the shank measured 7.5 mm by 8 mm in cross-section and measured 139 mm in length. The square head measured 15 mm by 13.5 mm in area. This metal fastener has no contextual relation with the timber as it is tacked onto the plank. The magnet did not detect any ferrous metal in the timber. The timber displayed evidence of organic and metal sheathing surface coverings. The organic woven matting is similar to other examples recorded in the collection. The metal sheathing on top of the matting is heavily corroded and torn. The approximate length of the extant sheathing measured 90 mm by 35 mm wide and 0.5 mm thick. In addition, copper alloy sheathing tacks were also present. They are square shanked and measured 27 mm in length with 11.5 mm diameter heads. The lengths of the tacks do not reflect the original total length as the ends have been clenched over. The clenching appears to have been part of the souveniring activity. The smaller tacks measured 2 mm square with the larger tacks measuring 6.5 mm by 5 mm in cross-section through the shank. Distances between tacks measured 90 mm, although this is probably the measurement along the horizontal axis of the original sheathing sheet. The metal sheathing did not contain maker’s stamps. No construction or tool marks exist on the timber. Fibre and metal samples were collected for identification and further analyses.

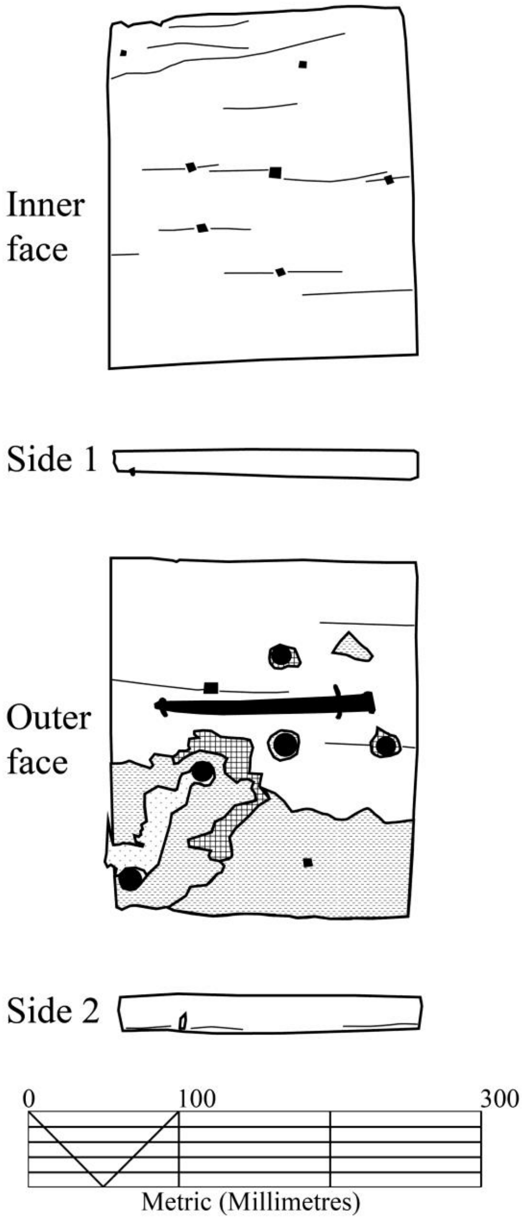

Figure 71. END_029 sacrificial timber drawing.

5.3.5.4 END_030 Sacrificial timber sheathing

This sacrificial sheathing plank's condition is fair and it has been clearly cut from the ship with no conservation treatment. No timber joints could be identified, although the timber conversion is tangential. The preserved length measured 484 mm with a preserved moulded measurement of 265 mm (Figure 72). The maximum thickness measured 24 mm. No metal fasteners or treenails were evident on this timber fragment. The magnet did not detect any ferrous metals. Metal sheathing and organic surface coverings are evident on the outer face of the timber. A woven material is located between the timber and metal sheathing. The extant dimensions of the metal sheathing measured 515 mm long, 295 mm wide and 0.5 mm thick. There appeared to be two separate sheets of sheathing which gave an overlap of 33 mm. The extant sheathing tacks are square in cross-section and their lengths measured c.30 mm. The head diameters measured c.12 mm and are irregular in shape, possibly due to the manual manufacturing process. The distances between tacks along the vertical axis is approximately 39 mm and 125 mm along the horizontal axis. No makers stamps associated with the sheathing was located. No construction or tool marks exist on the timber faces. Metal and fibre samples were collected for analysis. No wood sample was collected as there was no appropriate place to extract a piece without damaging the timber.

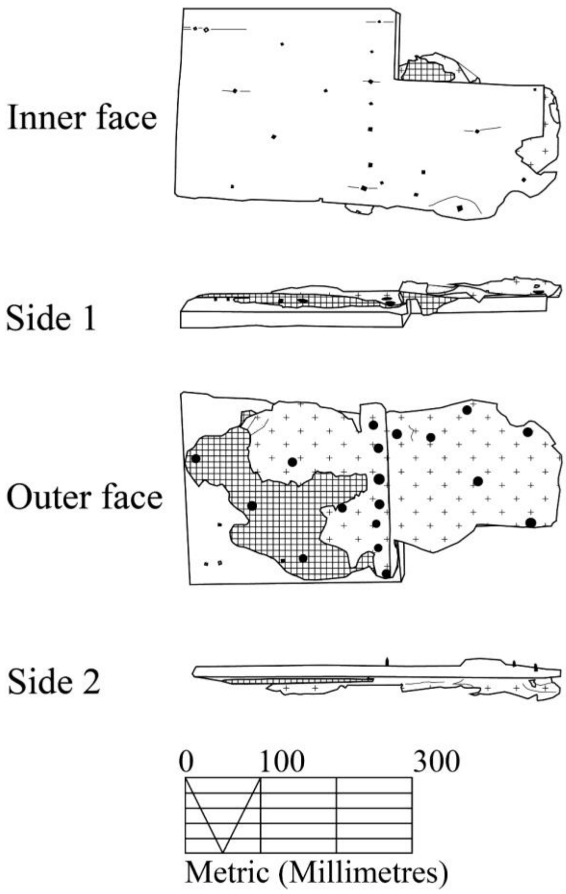

Figure 72. END_030 sacrificial timber and metal sheathing drawing.

5.3.6 Ceiling planking

5.3.6.1 END_027 Ceiling plank fragment

This ceiling plank is in a fair condition. It is broken on one end and cut on the opposite end, which is likely to be a modern cut. This timber did not feature any diagnostic timber joints. The timber was converted tangentially from the parent tree. The preserved length measured 1,065 mm (Figure 73). The maximum moulded face measured 286 mm by 63 mm thick. Three small dowels visible in the timber measured 15 mm in diameter. The round dowels appear to be driven into squarish holes. They did not have wedges inserted into them and are probably pegs. There were no extant metal fasteners, however, the magnet detected ferrous metal consisting of iron staining around square holes measuring 14.5 mm by 14.5 mm in area. Nail impressions left in the timber suggest these iron fasteners could have had large heads with washers. This impression measured 45 mm in diameter. No surface coverings were present on the timber including any impressions left behind from sheathing tacks or nails. No construction or tool marks were visible on the timber faces. One timber sample was collected for identification.

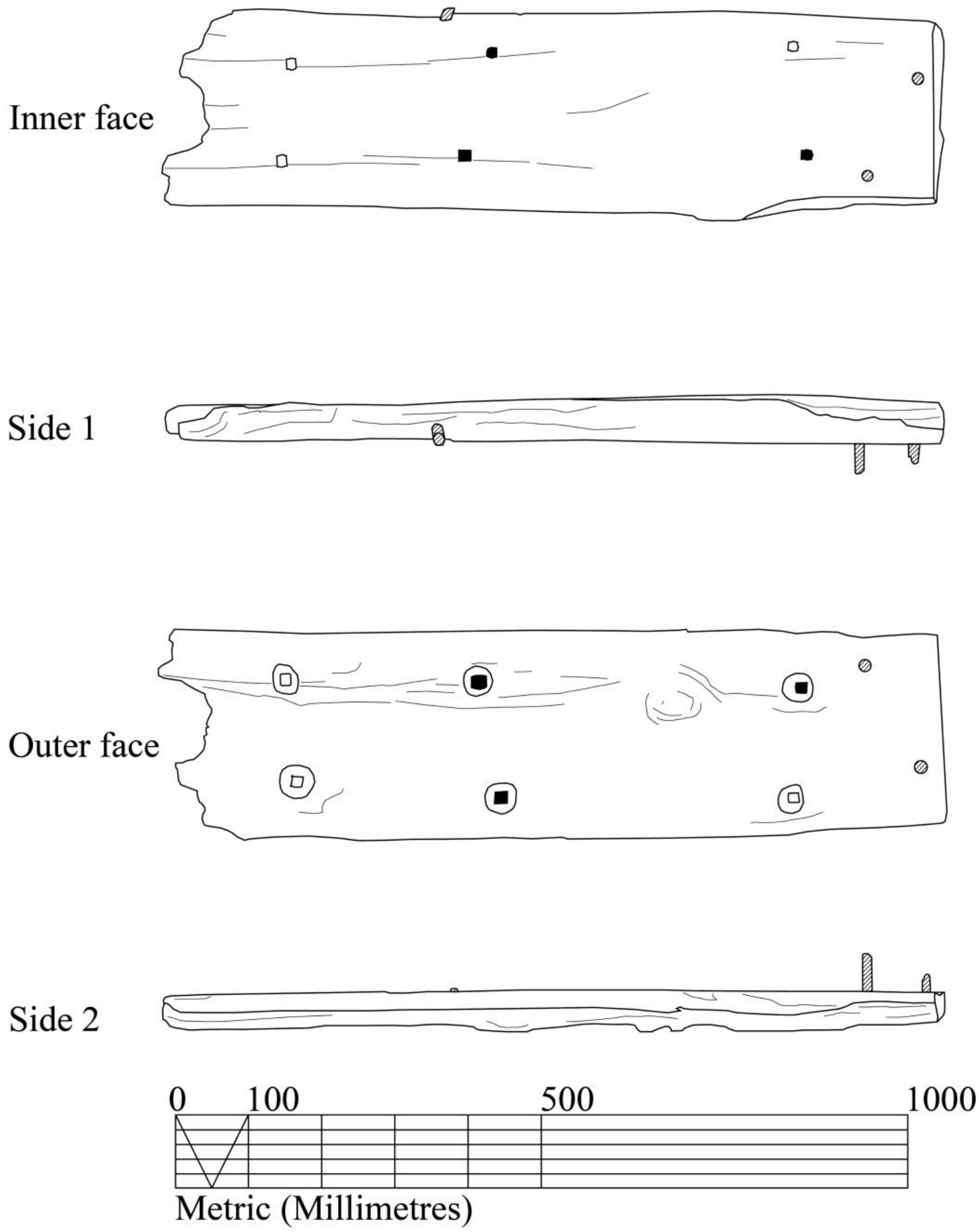

Figure 73. END_027 ceiling plank fragment drawing.

5.3.7 Unidentified

5.3.7.1 END_006 unidentified timber

This undiagnostic timber is in a fair state of preservation with one face badly degraded by marine borer. Notches are cut into the sides of the timber suggesting other timbers were closely fitted to this piece. The timber is bevelled on both sides and tapers towards one end. The original tree was halved to form the timber. There is a possible halved scarf joint at one end, although it is unclear if this scarf joint is original or if it was created during the salvage of the timber. The timber's preserved dimensions measure 3,083 mm long, 365 mm moulded and 135 mm thick. Nine extant treenails in the timber have varying levels of preservation (Figure 74). The treenails measure 38 mm in diameter and do not contain wedges. A round ferrous fastener measures 30 mm in diameter. No surface coverings are evident on the timber. No construction marks were visible on the timber, whereas tool mark impressions are preserved in the timber. Small tool impressions and possible saw marks are visible on the inner face and side 2. Two wood samples were collected for identification; timber sample T01 was collected from the main timber and T02 was collected from a treenail as a representative sample. It is possible the timber is from the interior side of the ship and was once associated with the keel or keelson.

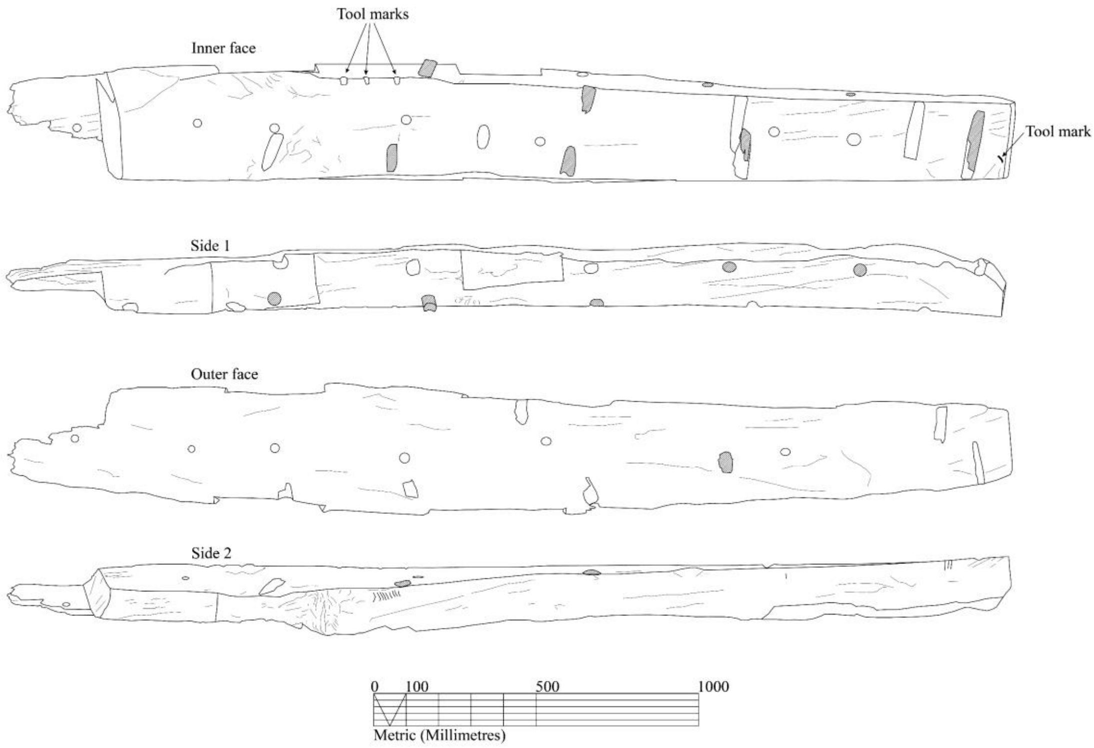

Figure 74. END_006 unidentified timber fragment drawing.

5.3.7.2 END_008 unidentified timber

The function of this timber could not be determined, however, it still displayed diagnostic ship construction features (Figure 75). The timber is in a fair state of preservation and showed it was tangentially converted. No original joints were evident although one end is sawn and is likely to be a result of modern salvage activity. The timber measured a maximum thickness of 105 mm, while the preserved dimensions measured 1,146 mm in length by 185 mm moulded. The timber contains two extant treenails that measured a maximum 34 mm in diameter. The treenails had no preserved wedges as the ends were degraded. No metal was detected, and no surface coverings were present. It may be possible, however, that metal sheathing once existed due to tack hole impressions left in the timber. The holes are square in shape and measured approximately 3 mm and 5 mm square. The holes measured between 3 mm and 17 mm deep. As an observation, the treenails extended past the timber on the side of the possible sheathing tack holes suggesting there might have been another timber attached to the same side. On further inspection, however, the treenails were sitting loose and may have moved in their holes during the salvage process. No construction marks were seen on the timber, while a possible tool mark may be present on the inner face in the form of a square nail impression. One wood sample was collected for identification.

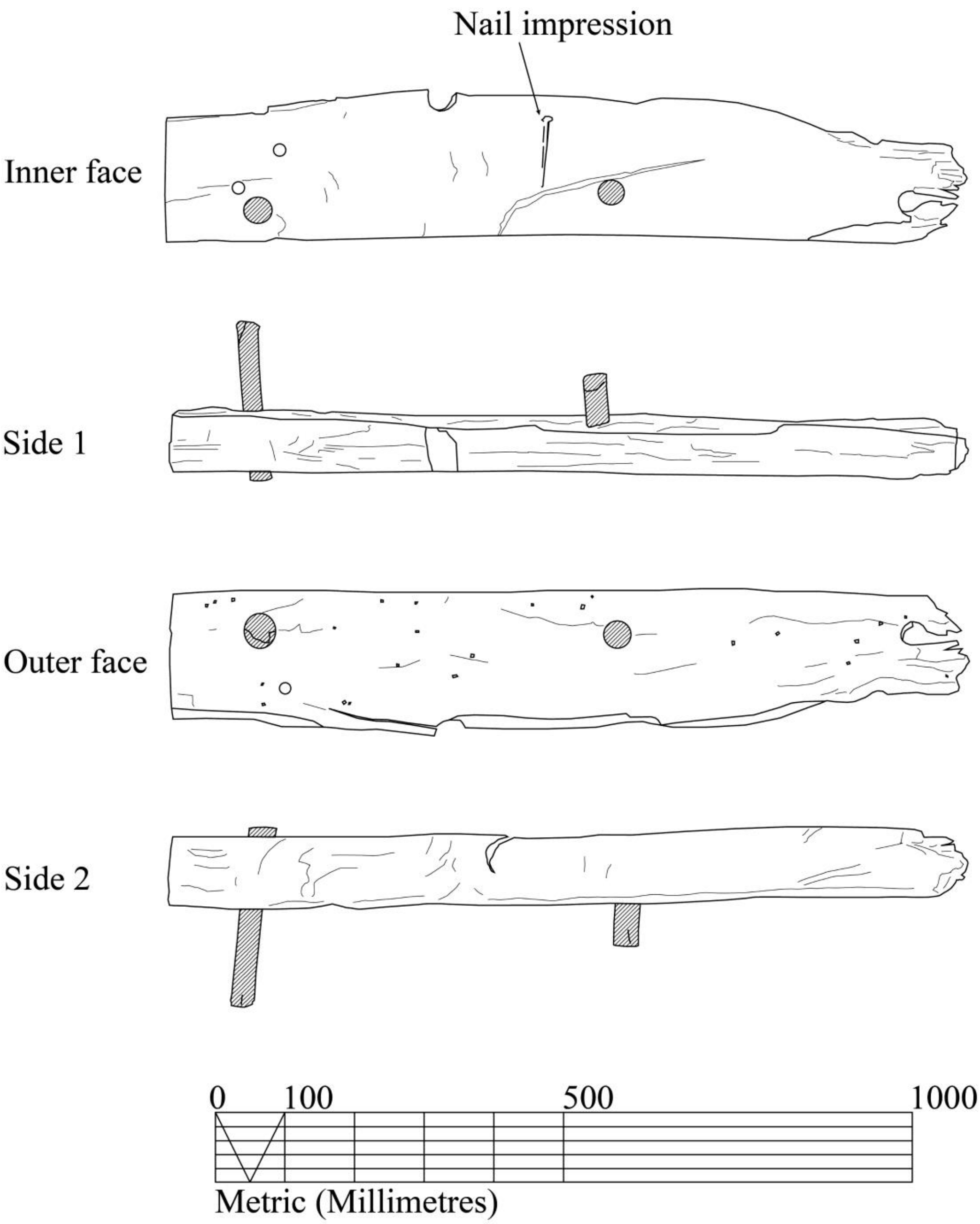

Figure 75. END_008 unidentified timber fragment drawing.

5.3.7.3 END_009 unidentified timber

This timber is in a poor state of preservation and the original function could not be determined. The wood has been exposed to marine organisms and may have suffered from dry rot while in storage. Both ends were broken or degraded, however, the grain pattern suggests it has been quartered from the original tree. No timber joints exist due to the current degradation. The fragment's preserved dimensions are 1,306 mm long by 174 mm moulded and 85 mm thick (Figure 76). Five extant treenails measured up to 38 mm in diameter with their lengths not known due to their incompleteness. The treenails did not contain any wedges. No metal fasteners were extant except for empty square holes that measured 6 mm by 3 mm in surface area and are only present on the outer face. The magnet did not detect any ferrous metal. There was no evidence of surface coverings on the timber faces. No construction marks were visible on the timber, although tool marks are present in the form of possible adze work. A wood sample was collected for identification.

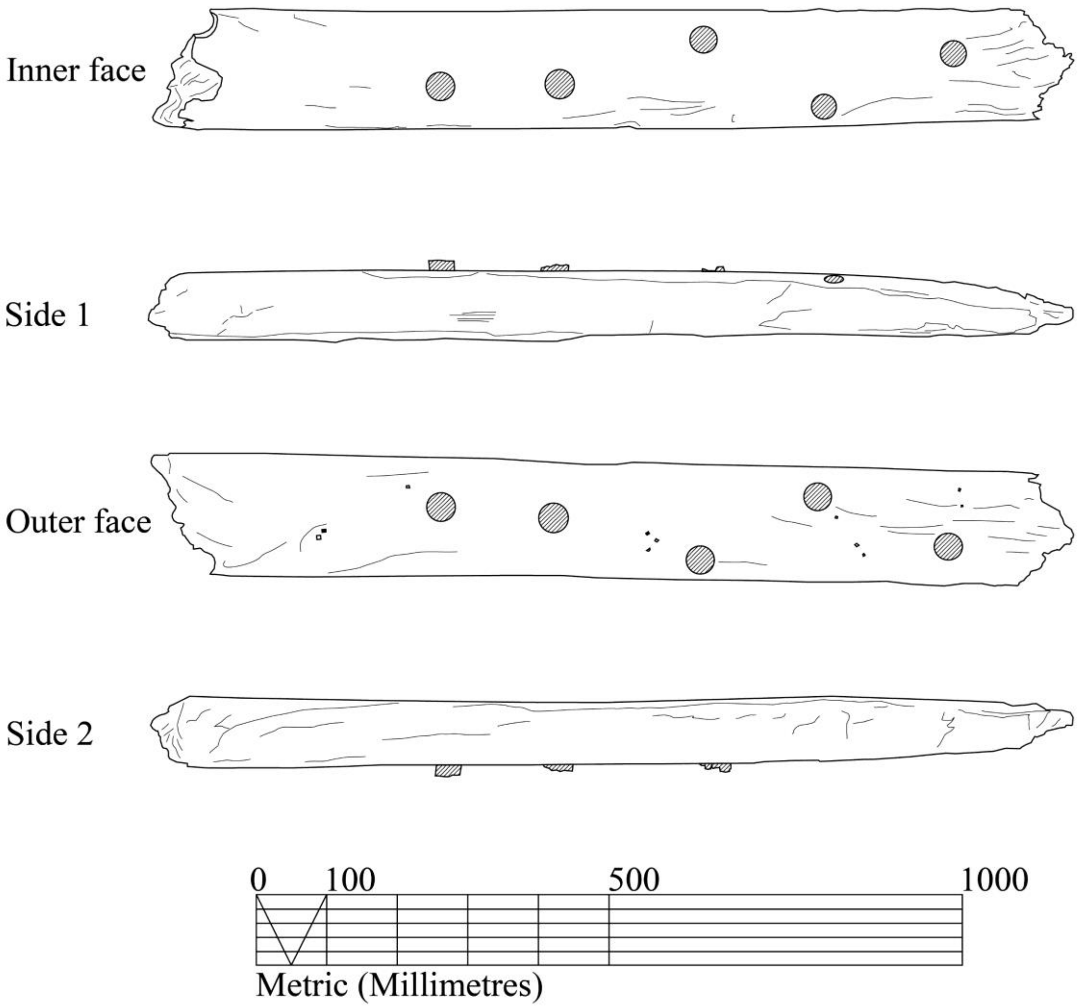

Figure 76. END_009 unidentified timber fragment drawing.

5.3.7.4 END_031 unidentified timber

This undiagnostic timber is in a poor state of preservation. It shows the timber has a tangential conversion. No joints are evident on the timber. The preserved dimensions of the timber are 416 mm long, 95 mm moulded and 40 mm thick. No fastenings are evident and no ferrous metal was detected by the magnet. No surface coverings were visible and it is not known if sheathing tacks were at one time present. The timber did not display any construction or tool markings. The timber's grain colour appears lighter than the rest in the collection. No samples were taken because the timber has no contextual information.

5.3.7.5 END_032 unidentified timber

It is possible this timber is a plank fragment, although it has limited diagnostic features. The condition of the timber is poor and heavily degraded. There are no visible timber joints and its conversion could not be determined. Its preserved dimensions are 283 mm long by 84 mm moulded and 65 mm thick. This fragment contains no fasteners, however, one possible treenail hole measured 42 mm in diameter. The hole is preserved as a half-circle as it is positioned on one edge of the timber. No ferrous metal was detected and there is no evidence of surface coverings, including sheathing tacks. The degraded faces may have removed any evidence of this over time. The timber did not display any construction or tool marks. This timber was not sampled due to it showing no diagnostic features which would aid identifying its function.

5.3.7.6 END_033 unidentified timber

The condition of this small fragment of timber is poor and degraded. The original function is unknown, and it no longer exhibits any diagnostic features. The preserved dimensions are 169 mm long by 60 mm moulded and 40 mm thick. There is no evidence of fastenings. The magnet did not detect any ferrous metal. There is no evidence of surface coverings, including sheathing tacks. The timber did not show signs of construction marks or tool impressions. No samples were collected for analysis or identification.

5.3.7.7 END_034 unidentified timber

This timber fragment's function was not identified. The condition of this timber is poor and highly degraded. There is no evidence of timber joints. Its preserved dimensions are 233 mm long by 76 mm moulded and 55 mm thick. No fasteners were evident on the timber. No ferrous metal exists in the timber. There are no surface coverings, and no indications of sheathing tacks. The timber does not show any construction or tool marks. Therefore, this timber was not sampled for analysis.

5.3.7.8 END_039 unidentified timber

This timber fragment was identified as a possible piece of a ship's spar. It is very worn and displays four possible fastener or rigging holes. The timber measured preserved dimensions of 1,144 mm in length, 124 mm moulded and 80 mm thick. No timber joints were evident. There are no extant fastenings. The magnet confirmed iron staining is present on the timber. There are no surface coverings and the timber does not show signs of construction or tool marks. Although included in the *Endeavour* timber collection, museum records do not confirm this fragment is from the same shipwreck site and therefore falls outside the scope of this thesis.

In summary, the *Endeavour* timbers recorded at the Southland Museum and Art Gallery Niho o te Taniwha did not have any preserved lengths. Thirteen timbers presented maximum moulded dimensions, three timbers presented maximum sided measurements and thirteen timbers presented maximum thickness measurements. These measurements, along with recorded fasteners, tool marks and additional materials, are comparable to the other primary case studies.

5.3.8 Contextualising the timbers

The timbers recorded in the Southland Museum and Art Gallery Niho o te Taniwha, provide the best opportunity to reconstruct the ship's hull lines. Through observing the likeness between several timbers, END_001, END_002, END_003, END_015 and END_026, the individual 3D digital models of these timbers were combined to assess contextual information (Figure 77). Additionally, the garboard strake END_019 indicated it was originally shaped to the rabbet recorded along the keel timbers. This was further confirmed by the alignment of corresponding treenail holes (Figure 78).

As a result, a section of the lower bilges is reconstructed giving provenance to the timbers from where the timbers originated in the hull. The reassembled keel components and garboard strake have been overlaid on the ship's lines plans to determine its position in the hull (Figure 79). The angles of the rabbet and curvature of the garboard strake positions the timber aft of midships, closer to the stern post and with the garboard strake positioned on the starboard side. This positions the scarf joint approximately 2.17 metres (7.14 ft) from the stern post.

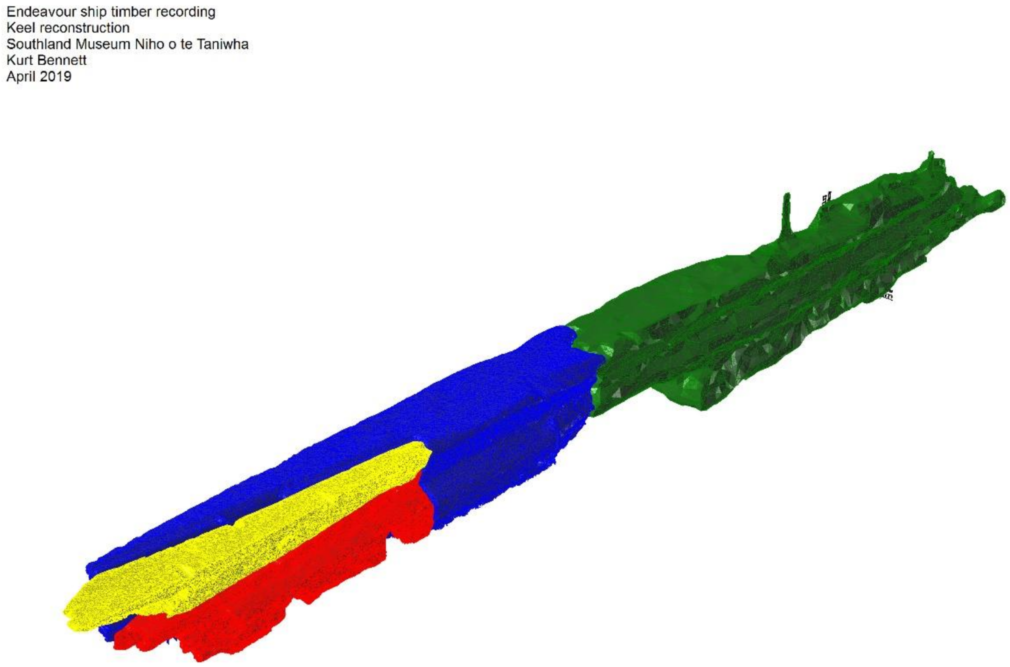

Figure 77. *Endeavour* keel timbers END_001 and END_002 (green), END_003 (blue), END_015 (yellow) and END_026 (red) digitally reassembled.

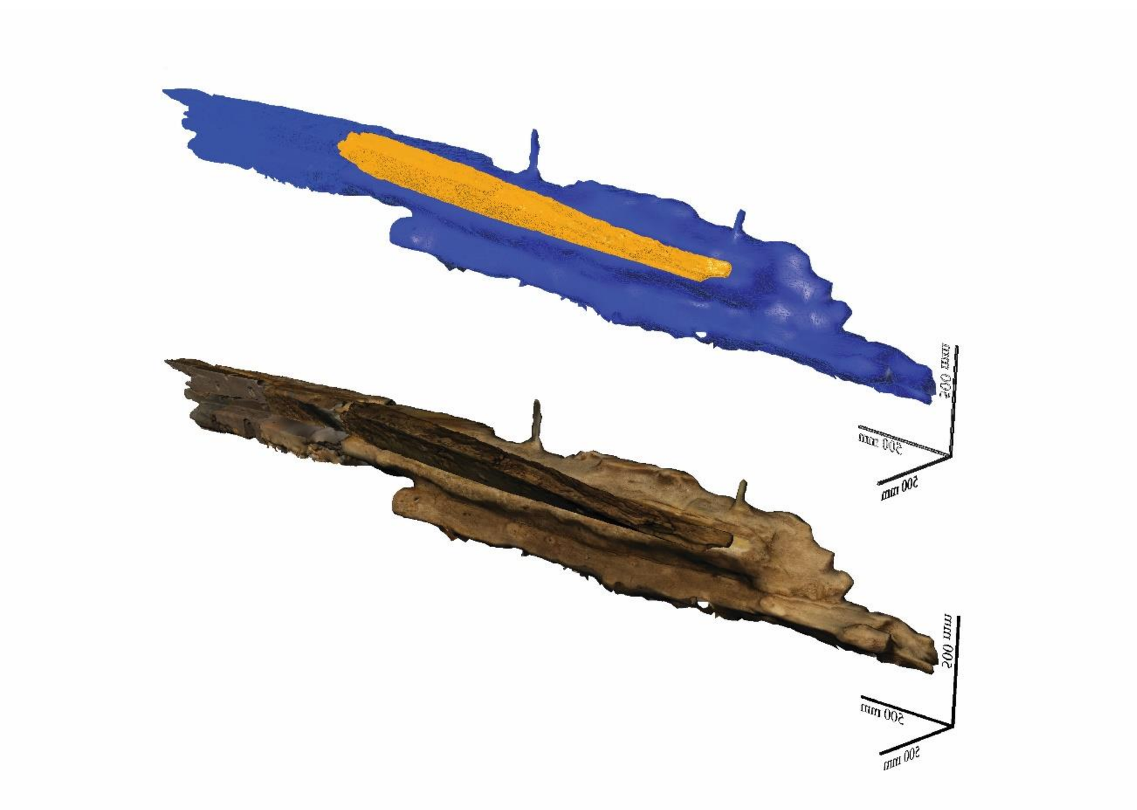

Figure 78. Reconstructed keel (blue) with the garboard strake END_019 (orange) positioned (top image) and a full colour render showing the keel assembly (bottom image).

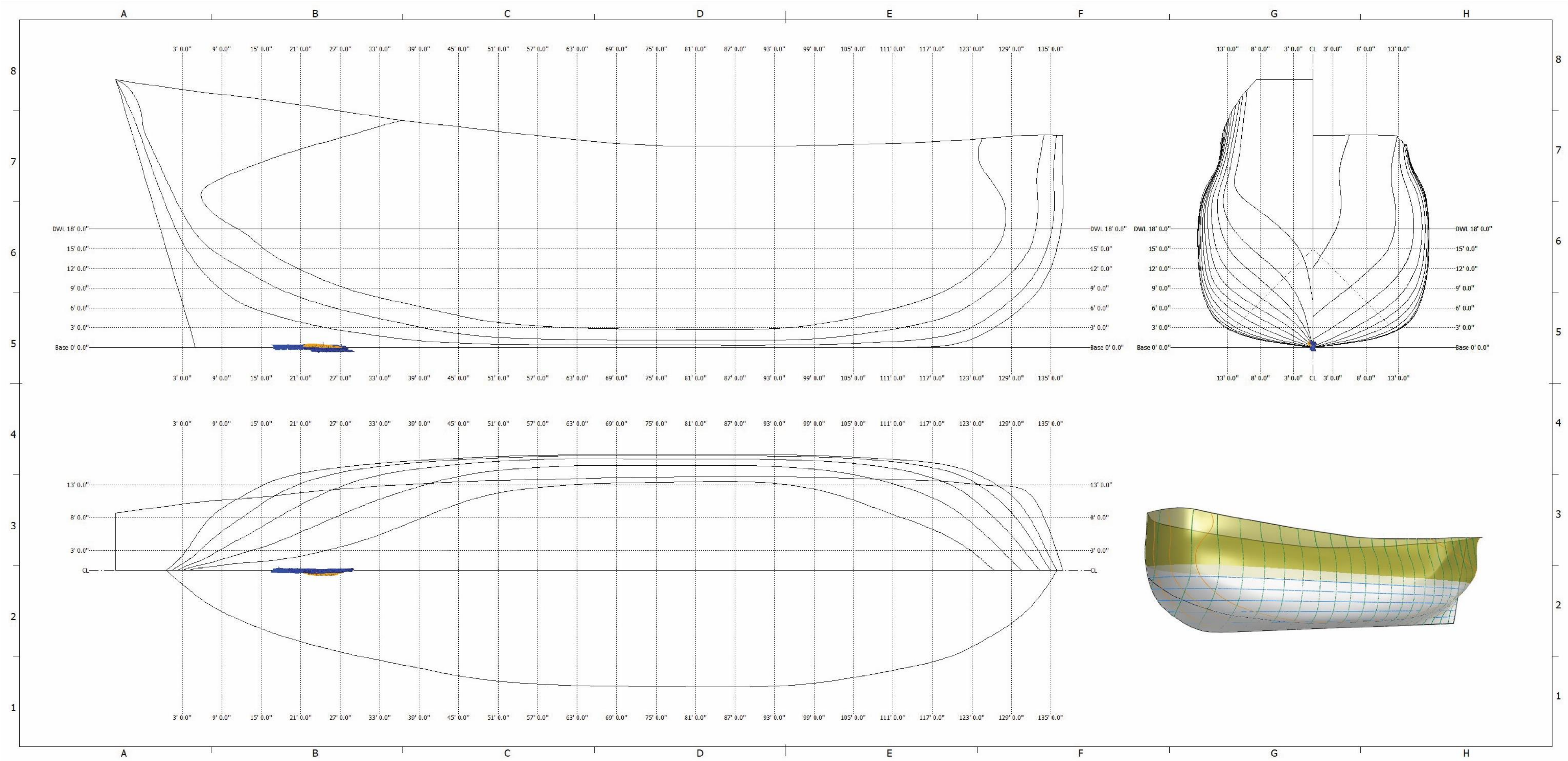

Figure 79. Keel assembly overlayed onto the *Endeavour* lines plan.

5.3.9 Loose treenails

Eleven loose treenails retained in the *Endeavour* ship collection at the Southland Museum and Art Gallery Niho o te Taniwha were recorded and are included in this study. These loose artefacts, although limited in their contextual information, provided an opportunity to record their dimensions. This complements the data on the types of fasteners used for the construction of *Endeavour*. Their measurements are also used for comparing to other treenails found in context in the larger timber remains of HMS *Buffalo* and *Edwin Fox*. The results from the treenail recording are presented in Table 7 and the best-preserved treenail (END_041) is shown in Figure 80.

Table 7. Loose treenails recorded in the *Endeavour* ship collection, Southland Museum and Art Gallery Niho o te Taniwha.

Registration #	Accession #	Function	Length (mm)	Diameter (mm)	Wedge	Sampled	Notes
END_041	95.71.2(b) [81939]	Treenail (loose)	211	37	No	No	Incomplete. Driving end is shaped.
END_042	95.71.4 (b) [81941]	Treenail (loose)	109	36.5	No	No	Incomplete.
END_043	95.71.4 (c) [81941]	Treenail (loose)	107	38	No	No	Incomplete.
END_044	95.71.10 (b) [81947]	Treenail (loose)	190	41	No	No	Incomplete. Squared and shaped on one end.
END_045	95.71.11 (e) [81948]	Treenail (loose)	143	42	No	No	Incomplete.
END_046	95.71.11 (f) [81948]	Treenail (loose)	118	40.5	No	No	Incomplete.
END_047	95.71.11 (g) [81948]	Treenail (loose)	106	38.5	No	No	Incomplete.
END_048	95.71.11 (h) [81948]	Treenail (loose)	95	38	No	No	Incomplete.
END_049	95.71.11 (i) [81948]	Treenail (loose)	93	37.5	No	No	Incomplete.
END_050	95.71.11 (j) [81948]	Treenail (loose)	82	37	No	No	Incomplete.
END_051	95.71.21 (b) [81958]	Treenail (loose)	104	38.5	No	No	Incomplete.

Figure 80. Loose treenail (END_041) from the *Endeavour* collection, Southland Museum and Art Gallery Niho o Te Taniwha (Photograph: Kimberley Stephenson, 2019).

5.3.10 Wood identification

Twenty-eight timbers and fragments from the *Endeavour* collection were sampled for wood identification. Out of this, 26 were positively identified to a genus level. The results are presented in Table 8.

Table 8. Wood samples from the Southland Museum *Endeavour* ship timber collection.

Project sample #	**Scientific name**	**Common name**	**Function**
END001_95.71.1_T01	*Ulmus* spp.?	Elm	Possible false keel
END002_95.71.1_T01	*Ulmus* spp.?	Elm	Possible keel
END003_95.71.2(a)_T01	*Ulmus* spp.?	Elm	Keel
END005_83.2002(b)_T01	*Tectona grandis*	Teak	Plank
END006_95.71.3(a)_T01	*Ulmus* spp.?	Elm	Unknown
END006_95.71.3(a)_T02	*Quercus* spp.?	Oak	Treenail
END007_95.71.15(a)_T01	*Quercus* spp.?	Oak	Possible futtock
END008_95.71.16(a)_T01	*Ulmus* spp.?	Elm	Unknown
END009_95.71.17(a)_T01	*Quercus* spp.?	Oak	Not determined
END010_95.71.18(a)_T01	*Ulmus* spp.?	Elm	Possible outer plank
END011_95.71.19(a)_T01	*Ulmus* spp.?	Elm	Possible plank
END012_95.71.20(a)_T01	Undetermined	Undetermined	Possible plank
END013_95.71.21(a)_T01	*Quercus* spp.?	Oak	Possible futtock
END014_95.71.22(a)_T01	*Ulmus* spp.?	Elm	Possible plank
END016_95.71.21(a)_T01	*Quercus* spp.?	Oak	Possible plank
END017_95.71.10(a)_T01	*Quercus* spp.?	Oak	Possible part of the keel
END017_95.71.10(a)_T02	*Quercus* spp.?	Oak	Treenail
END018_95.71.4(a)_T01	*Ulmus* spp.?	Elm	Plank
END019_95.71.5(a)_T01	*Ulmus* spp.?	Elm	Garboard strake
END020_95.71.6(a)_T01	*Ulmus* spp.?	Elm	Possible plank
END021_95.71.11(a)_T01	*Ulmus* spp.?	Elm	Plank
END022_95.71.9_T01	*Ulmus* spp.?	Elm	Possible plank
END023_95.71.12_T01	Undetermined	Undetermined	Possible plank
END024_95.71.7(a)_T01	*Ulmus* spp.?	Elm	Plank
END025_95.71.8_T01	*Ulmus* spp.?	Elm	Possible outer plank
END026_95.71.14(a)_T01	*Ulmus* spp.?	Elm	Keel
END027_0000.3754_T01	*Tectona grandis*	Teak	Possible plank
END028_83.2115.1_T01	*Pinus* spp.?	Pine	Possible plank

5.3.11 Metal analysis

Combined with the timber collection were several loose sheathing tacks. It is probable that these have come from other sheathing fragments or were donated to the museum in the past and have been maintained as part of the collection. These isolated materials were deemed appropriate for sampling by the museum staff with the tacks chosen for sampling, presented here. Recordings of other metal fasteners, including a keel bolt and copper alloy fastener, are included in this section.

5.3.11.1 END_036 sheathing tack

The tack’s square shank measured 27 mm in length and the head diameter measured 11 mm in diameter (Figure 81). While the tack cannot be traced back to a specific location in the ship, it is included here as a sacrificial sample to examine its metal composition. Furthermore, by sampling this tack it provides new information without damaging other similar better-preserved museum artefacts.

Figure 81. Sheathing tacks END_036 (far right), END_037 (centre), from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha (Photograph: Kimberley Stephenson, 2019).

5.3.11.2 END_037 sheathing tack

This sheathing tack came from associated loose tacks and nails found with other loose sheathing fragments in the *Endeavour* collection. The shank is square in shape and measured 32 mm in length. The head measures 12 mm in diameter. This selection represents a slightly longer variant of a sheathing nail and could have a different manufacturing composition and function than the other sheathing tacks.

5.3.11.3 END_038 keel bolt

This artefact is a possible copper alloy keel bolt and it is included in the results because its dimensions are comparable with the keel bolt holes found in situ in the main keel timber. The bolt is in a good state of preservation with only general surface corrosion, however, one end is bent and twisted and probably caused by modern salvage processes (Figure 82). The head of the bolt appears to be hammered and the opposite end does not look complete (sawn off). The shank of the bolt is round and measured 32.5 mm in diameter with the approximate preserved length measuring 1,580 mm. No maker’s stamps were visible on the bolt. It was not sampled for metal analysis.

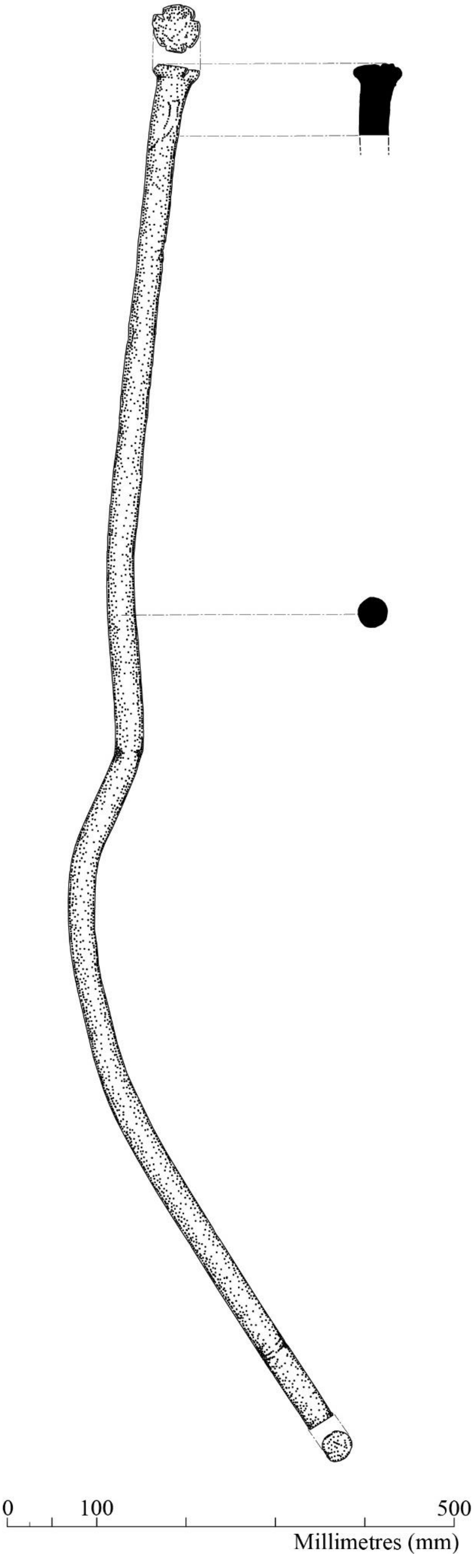

Figure 82. Loose keel bolt (END_038) drawing, from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha.

5.3.11.4 END_052 copper alloy fastener

This artefact is a copper alloy fastener with an undiagnostic timber fragment (Figure 83). Only the fastener was recorded because it is similar in dimensions to other fastener impressions recorded on the *Endeavour* timbers for this study. The head appears to be hammered, causing it to flower and the opposite end has a washer. The shank is round and measures 40 mm in diameter by 315 mm long.

Figure 83. Copper alloy fastener (END_052) from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha (Photograph: Kimberley Stephenson, 2019).

In addition to the two sheathing tacks described previously, hull sheathing from END004, END029 and END030 were sampled. These materials were sampled to understand the differences in metal composition between the sheathing tacks and hull sheathing. The collected samples are summarised in Table 9 with results from analyses presented in Table 10.

Table 9. Metal samples collected from the Southland Museum and Art Gallery Niho o te Taniwha *Endeavour* ship timber collection.

Museum sample number	**Analysis sample number**	**Description**
END004_83.2002_M01	END004	*Endeavour* hull sheathing
END029_97.75_M01	END029	*Endeavour* hull sheathing
END030_2004.938.243_M01	END030	*Endeavour* hull sheathing
END36_0000.4856.2(t)_M01	END036	*Endeavour* sheathing tack
END37_0000.4856.2(t)_M01	END037	*Endeavour* sheathing tack

Table 10. *Endeavour*'s sheathing and tacks elemental composition results.

	Wt %							Atomic %						
Description	**C**	**Fe**	**Cu**	**Zn**	**Sn**	**Pb**	**Total**	**C**	**Fe**	**Cu**	**Zn**	**Sn**	**Pb**	**Total**
END4: spectrum 1	12.76	-	87.24	-	-	-	100	43.62	-	56.38	-	-	-	100
END4: spectrum 2	13.47	-	86.53	-	-	-	100	45.16	-	54.84	-	-	-	100
END4: spectrum 3	12.25	-	87.75	-	-	-	100	42.48	-	57.52	-	-	-	100
END29: spectrum 1	9.37	-	90.63	-	-	-	100	35.36	-	64.64	-	-	-	100
END29: spectrum 2	9.90	-	90.10	-	-	-	100	36.77	-	63.23	-	-	-	100
END29: spectrum 3	12.59	-	87.41	-	-	-	100	43.24	-	56.76	-	-	-	100
END30: spectrum 1	15.53	-	84.47	-	-	-	100	49.30	-	50.70	-	-	-	100
END30: spectrum 2	14.97	-	85.03	-	-	-	100	48.22	-	51.78	-	-	-	100
END30: spectrum 3	13.96	-	86.04	-	-	-	100	46.19	-	53.81	-	-	-	100
END36: spectrum 1	9.89	1.07	75.19	8.17	4.06	1.61	100	37.55	0.88	53.96	5.70	1.56	0.35	100
END37: spectrum 1	8.97	-	79.56	2.59	2.68	2.68	100	35.50	-	59.52	1.88	2.48	0.61	100

The elemental analysis confirms *Endeavour*’s hull was sheathed in pure copper. The weight percentages vary between 85.03 and 90.63 per cent. The copper has some carbon inclusions varying from 9.37 to 15.53 per cent. The tacks used to fasten the metal sheathing were manufactured using 75.19 to 79.56 per cent copper, 2.59 to 8.17 per cent zinc, 8.97 to 9.89 per cent carbon, 4.06 to 6.20 per cent tin, 1.61 to 2.68 per cent lead and negligible traces of iron. These results will be examined in the discussion chapter alongside the other case studies.

5.3.12 Fibre identification

In addition to the timbers sampled for fibre identification, two loose fibres are included in the sample set. These samples, END_035 and END_040, were attached to loose patches of possible caulking. These patches are kept separate in the collection with no record to indicate if they are associated with any of the timbers. They are similar, however, to the caulking recorded on the keel. Therefore, it is quite probable the fibrous material was at one time used as caulking in the ship’s hull.

5.3.12.1 END_035 caulking

This possible piece of caulking is similar in appearance to the caulking recorded on END_002. The fibrous remains measured approximately 165 mm long by 49 mm wide and 14 mm thick (Figure 84). Its context within the ship's hull structure is not known; however, this fragment is probably associated with other similar remains in the museum collection.

Figure 84. A possible piece of caulking (END_035) sampled from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha (Photograph: Kimberley Stephenson, 2019).

5.3.12.2 END_040 caulking

This artefact is a loose piece of caulking (Figure 85). It is included here because it was in a good state of preservation and therefore it was sampled for analysis. It appears similar to other remains of caulking found in context on other timbers in the museum collection.

Figure 85. Loose piece of caulking (END_040) sampled from the *Endeavour* collection, Southland Museum and Art Gallery Niho o te Taniwha (Photograph: Kimberley Stephenson, 2019).

A total of eight fibre samples were sent for identification to BIAX consultants. Six samples are identified positively as goat and wool with results listed in Table 11.

Table 11. Fibre samples from the Southland Museum *Endeavour* ship timber collection.

Sample #	Function	Fibre	Description
END002_95.71.1_F01	Possible keel	Undetermined.	Mineralised loose plant tissue. No fibres like flax hemp. No idea what it is. Probably very difficult/impossible to find out; badly preserved.
END003_95.71.2(a)_F01	Keel	Goat hair	-
END004_83.2002_F01	Plank	Sheep wool	Twisted bundles. Fibre diameter measures 20µm.
END010_95.71.18(a)_F01	Possible outer plank	Goat hair	-
END019_95.71.5(a)_F01	Garboard strake	Undetermined.	Mineralised lumps with pitch/tar. Tiny fragments of wood present. Badly preserved.
END029_97.75_F01	Outer plank	Sheep wool	Twisted bundles. Fibre diameter measures 20µm.
END030_2004.938.243_F01	Outer plank	Sheep wool	Twisted bundles. Fibre diameter measures 20µm.
END040_0000.2597 (c)_F01	Caulking (loose)	Goat hair	-

5.3.13 Organic analysis

No organic samples were collected from the Southland Museum and Art Gallery's *Endeavour* timber collection.

5.4 Summary

The recording of the museum's timber collections reveals insights into *Endeavour*'s hull construction and design adaptations. The timbers recorded are mostly associated with the area around the bilge including, false keel, keel, possible futtocks, hull planking and sacrificial planking. Digitally recorded timbers aided the reconstruction of part of the keel and to understand its provenance from the shipwreck site. The wood identification verifies the ship was constructed using a mixture of elm, teak and oak. Material analyses confirms the ship incorporated copper antifouling technologies in addition to natural and animal fibres for antifouling and possible waterproofing.

Chapter 6. HMS *Buffalo* results

6.1 Historical findings and hull design

HMS *Buffalo* (ex *Hindostan*) was not researched in archival depositories because there is already significant historical research published (see Riddle and Bithell 2015; Sexton 1984). Instead, the study combines information from previously published sources with new primary data collected from archaeological recording. The combined analyses present new information towards understanding the construction and design of the hull. Specifically, ship's lines have been redrawn and hull coefficients calculated to determine the shape of the ship. Historical scantling dimensions collected from the archaeological recording are presented in this chapter to allow for comparison with the other case studies. The ship's overall dimensions are summarised in Table 12 with metric conversions.

Table 12. Scantling dimensions as recorded for *Hindostan* (HMS *Buffalo*).

Description	**Metres**	**Feet**	**Inches**	**Tons**
Length overall	36.57	120	-	
Keel length for tonnage	30.09	98	8 7/8	
Extreme breadth	10.31	33	10	
Depth of hold	4.77	15	8	
Tonnage by measurement				589

6.1.1 Hull Lines

HMS *Buffalo*'s hull lines represent the shape of the hull in its three perspectives—the sheer, body and half-breadth (Figure 86). These lines are reproduced after Sexton's reconstruction (1984:174) and the ship's original plan, 'HMS *Buffalo*, Scale: 1:96. A plan showing the inboard profile, poop and forecastle decks, upper deck and orlop deck for '*Buffalo*' (1813), a purchased East Indiaman, as fitted in 1833 to carry female convicts to New South Wales, Australia. Signed by William Stone' [Master shipwright, Chatham Dockyard, 1830–1839], (National Maritime Museum, Greenwich, London, '*Buffalo*' 1813, ZAZ5552, https://collections.rmg.co.uk/collections/objects/85343.html). Measurements are given in feet to reflect the original scale and dimensions presented on the original plans. The lines plan produced for this thesis aids assessing the shape of the hull and calculating hull coefficients.

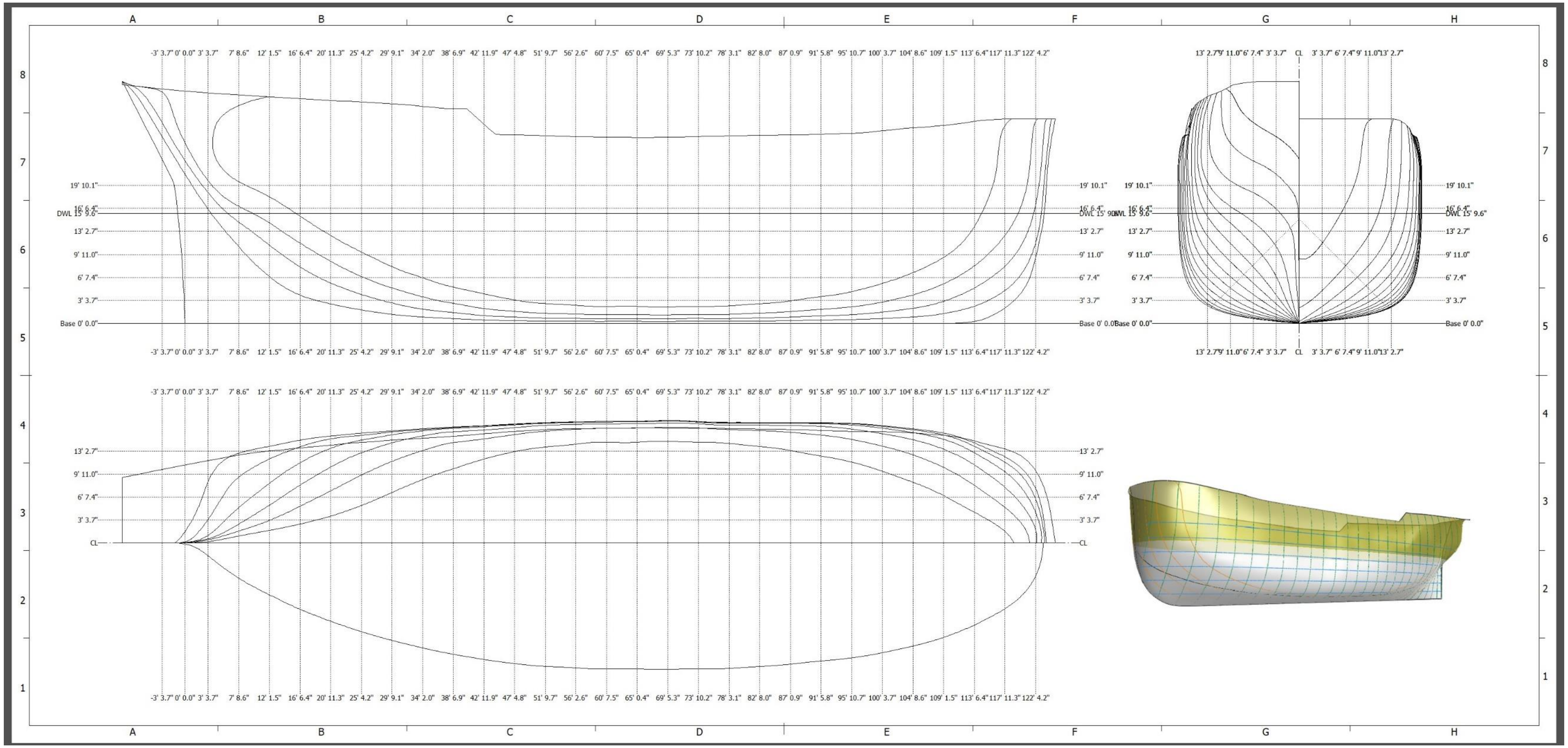

Figure 86. HMS *Buffalo* ship's lines plan.

6.1.2 Hull coefficients

The completed lines plan was used to calculate the coefficients using the hull parameters. The block coefficient is 0.7014, the prismatic coefficient is 0.7542 and the midship coefficient is 0.9299. These coefficients are used to asses changes in hull shape over time and are compared to those of *Endeavour* and *Edwin Fox*.

6.2 Mercury Bay Museum

In November 2017, the author visited the Mercury Bay Museum, Whitianga, Aotearoa New Zealand. The museum houses a small collection of materials from HMS *Buffalo*, which sunk in Mercury Bay. Through anthropogenic or environmental processes, recovered disarticulated ship materials have been donated or loaned to the museum and incorporated into their displays about local shipwrecks.

In May 2019, the public delivered additional ship timbers to the museum. These new timbers display construction and technology features which assist this study. The author visited the museum to record the new timbers that had been handed in by the public. Some of these timbers were kept in an individual's possession for decades, while other timbers were freshly recovered from the beach. A total of 12 additional timbers were recorded with the help of Siobhan Cox.

As a result, the new timbers were recorded with different registration numbers. For example, the first three timbers recorded in January 2018, were recorded as sequential numbers (i.e. 001, 002, etc). The May 2019 visit, however, recorded the timbers with a prefix BUF and a suffix following a sequential numbering system. Therefore, the timbers recorded in May 2019 were labelled as BUF_001, BUF_002, etc. A total of 12 timbers were recorded under this system in May. For consistency, the three timbers (001, 002 and 003) recorded in November 2017 were updated with the prefix 'BUF' and continued sequentially from the last entered timber identify, i.e. BUF_013, from the May 2019 data collection. Thus, 001 was amended to BUF_013, 002 to BUF_014 and 003 to BUF_015. These changes are noted in the database. The recorded timbers and their dimensions are summarised below in Table 13. The following presents the descriptions of the timber features and the copper sheathing.

Table 13. Summarised HMS *Buffalo* timber dimensions, Mercury Bay Museum.

ID	Accession #	Feature	Length (mm)	Moulded/Width (mm)	Sided (mm)	Thickness (mm)
BUF_001	2019.001.01	Sacrificial sheathing	3193	**209**		**24**
BUF_002	2019.002.01	Sacrificial sheathing	1050	131		28
BUF_003	2019.005.01	Sacrificial sheathing	3613	240		**23**
BUF_004	1980.016	Sacrificial sheathing	818	222		**27**
BUF_005	1980.004	Sacrificial sheathing	570	127		19
BUF_006	2019.003	Sacrificial sheathing	1194	123		25
BUF_007	2019.004	Sacrificial sheathing	1840	228		**25**
BUF_008	1980.016	Undetermined	345	175	80	
BUF_009	None	Sacrificial sheathing	618	184		21
BUF_010	3258	Undetermined	709	89	41	
BUF_011	1996	Outer plank	677	165		46
BUF_012	865	Undetermined	635	148	107	
BUF_013	230313/8	Knee	930	90	85	
BUF_014	31895/10	False keel	2040	**345**	**90**	
BUF_015	None	Futtock	860	**155**	**212**	
NB: **Bold** = maximum original measurements.						

6.2.1 False keel

6.2.1.1 BUF_014 false keel

This false keel fragment would have been attached to the main keel on the underside of the ship (Figure 87). The maximum length of the timber is unknown as one end appears to have been cut. The timber measured a preserved 2,040 mm long by a maximum 345 mm moulded and 90 mm sided. One end of the timber displayed a possible half-lapped scarf joint. Holes for staple fasteners are visible on the sides of the timber; however, the staples were not present at the time of recording. Surface coverings were present on the outer face in the form of metal sheathing. There was no fibre material present between the metal sheathing and the timber.

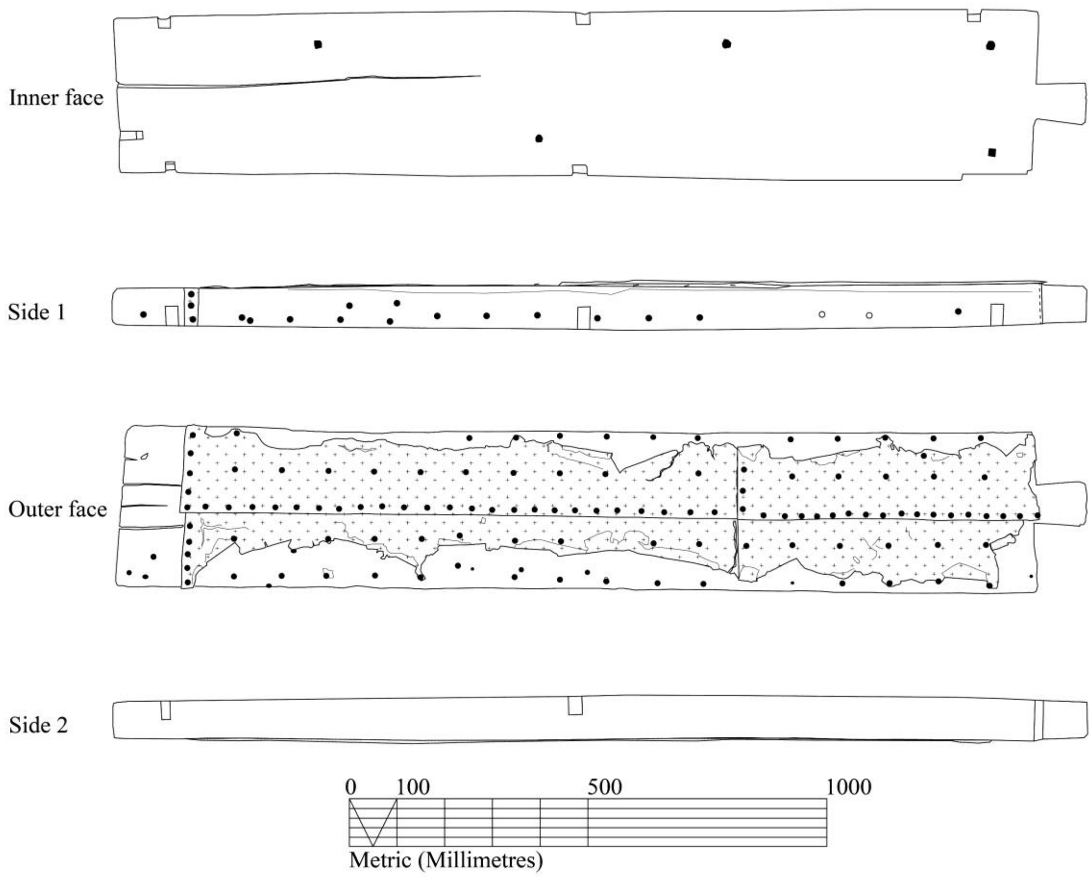

Figure 87. BUF_014 false keel timber fragment and metal sheathing drawing.

The metal sheathing, recorded separately as 001, consists of four separate sheets with a maximum length of 1,200 mm. The sheets maximum widths are unknown due to tearing and degradation of the metal. The sheathing is attached to the timber with tacks. The heads of the sheathing tacks measure 11 mm in diameter. Their lengths are unknown as they are embedded in the timber. The fastener patterning demonstrates that the tacks are placed in a regular square pattern with the greatest number of tacks following the perimeter of each sheet. The overlaps of sheets measure between 25 mm and 30 mm wide and indicate the direction of the bow and stern, i.e. the lapped dove tail scarf joint is located at the bow end of the timber. A wood and sheathing sample were collected for identification and analysis.

6.2.2 Futtock

6.2.2.1 BUF_015 futtock

This possible futtock fragment is shaped from one piece of timber (Figure 88). It measured a preserved 860 mm long by a maximum 155 mm moulded (across the centre) and 212 mm sided. Six treenails are positioned in an alternating pattern along the possible inner face of the timber. Four of the treenails are extant whereas there are two empty treenail holes. The treenails measured 25 mm in diameter. There were no metal fasteners evident in the timber. There were no recorded surface coverings, including metal sheathing and fibrous material. The timber was sampled for wood identification.

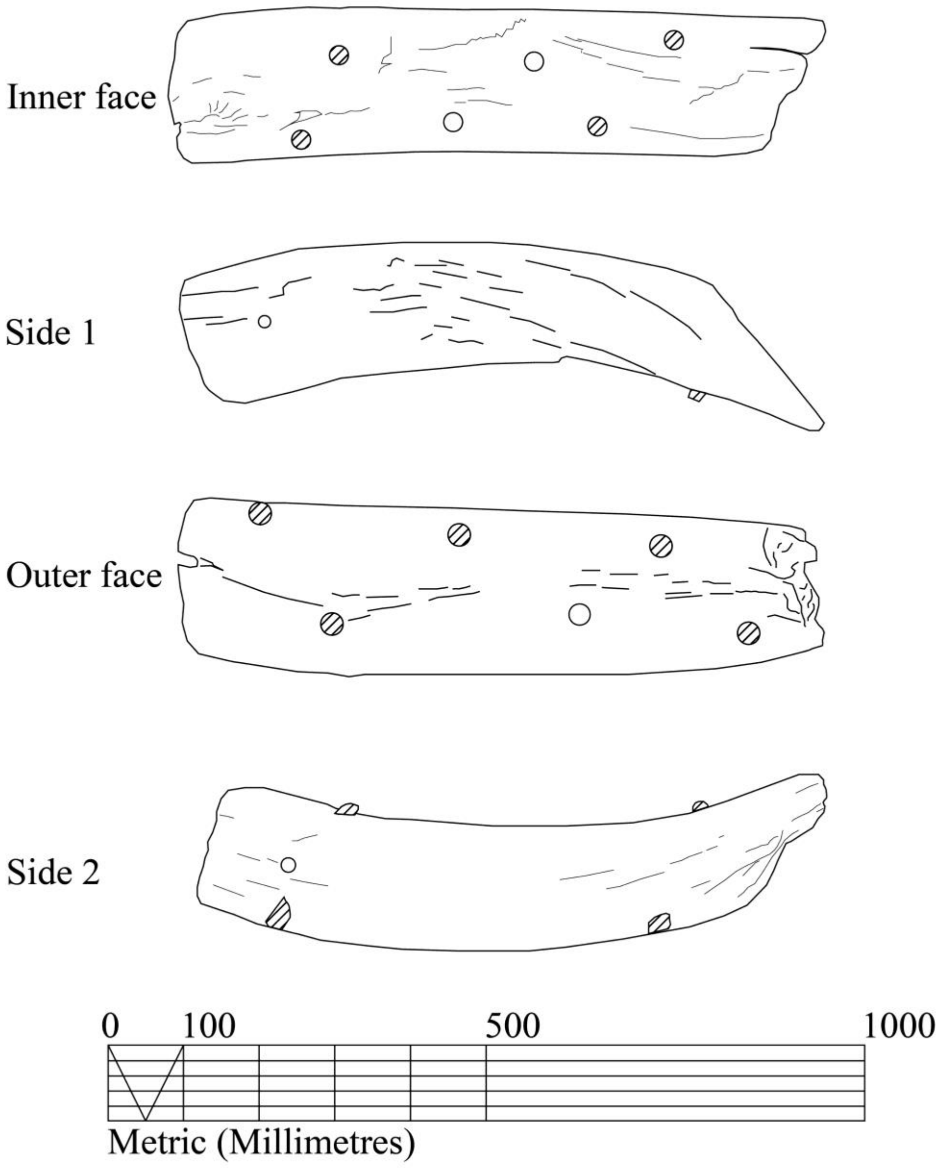

Figure 88. BUF_015 futtock timber fragment drawing.

6.2.3 Outer plank

6.2.3.1 BUF_011 outer plank

This timber fragment’s condition is poor and does not display evidence of any timber joints. The preserved fragment measures 677 mm long, 165 mm moulded and 46 mm sided. One small treenail located in the timber measures 17 mm in diameter, while its original length is unknown. There was no wedge present in the treenail. No ferrous metal was detected, and no surface coverings exist. Sheathing tacks were fixed in the timber and appeared to be square, however, overall dimensions including length and the diameters of heads could not be measured due to the tacks being badly corroded or damaged. Evidence of maker’s stamps, construction and tool marks were not identified. One wood sample was collected but taken from the degraded end of the timber so not to disrupt the condition of the timber. The treenail was not sampled.

6.2.4 Sacrificial timber sheathing

6.2.4.1 BUF_001 sacrificial timber sheathing

This sacrificial sheathing plank with associated pitch was assessed to be in a fair condition due to it having several broken edges and surface degradation. The timber had been converted tangentially from the parent tree. It measures 3,193 mm preserved length, 24 mm thick and has a maximum moulded dimension of 209 mm (Figure 89). A square metal nail which measures 8 mm by 7 mm in cross-section probably fastened the timber to the outside of the hull. No ferrous metal fasteners are present in the timber. Surface coverings include metal sheathing and a resinous substance. The metal sheathing measures 1229 mm in maximum length and 0.5 mm thick. The maximum width could not be measured. The sheets were fastened to the timber with tacks measuring 29 mm long and their heads 11 mm in diameter. The sheets overlap each other by 35 mm. No construction marks were observed on the timber. Wood, metal and organic samples were collected for further identification and analysis.

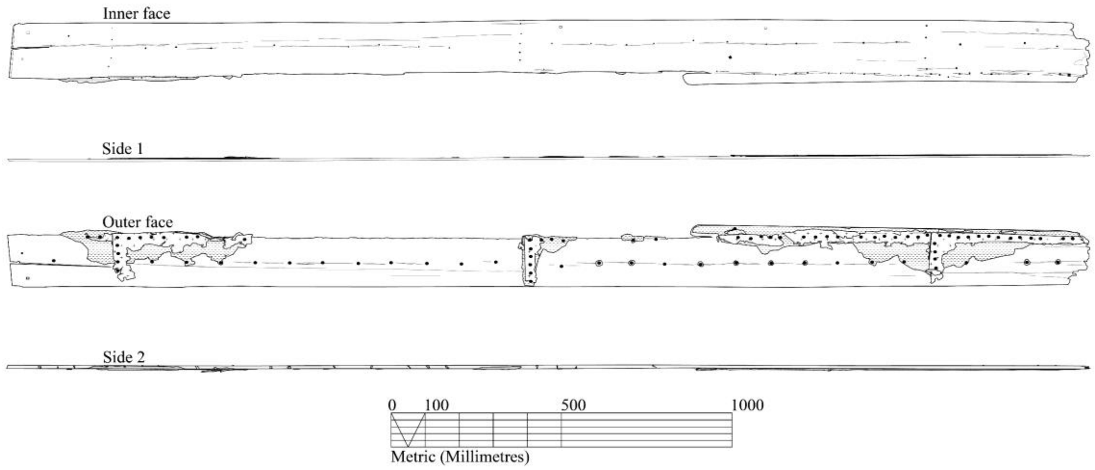

Figure 89. BUF_001 sacrificial timber sheathing fragment drawing.

6.2.4.2 BUF_002 sacrificial timber sheathing

This possible sacrificial sheathing plank's condition is considered fair because it is weathered and broken at both ends—displaying no evidence of joints. The timber measures 1,050 mm in preserved length, 131 mm moulded and 28 mm thick (Figure 90). Although both ends of the timber are broken, the visible timber grain indicates a tangential conversion. The timber contains empty square fastener holes that measure 7 mm by 6 mm in cross-section. The presence of any ferrous metal on the timber, especially the metal in the square fastener holes, remains undetected and unconfirmed. No construction marks or tool marks were detected on the timber.

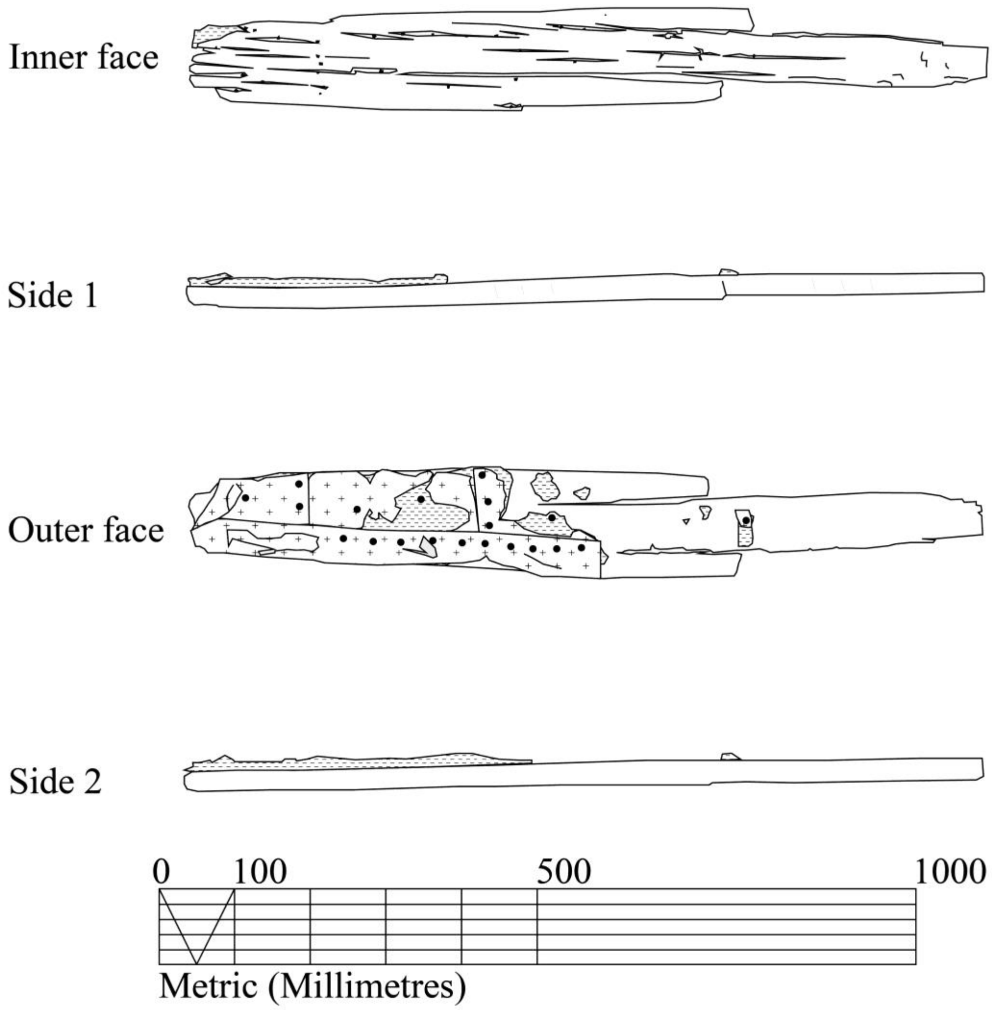

Figure 90. BUF_002 sacrificial timber sheathing fragment drawing.

The surface coverings include degraded metal sheathing without clear original dimensions and organic material. The sheathing thickness measures 0.5 mm. Diagnostic sheathing tacks have square shanks and they measure 28 mm in length. Their heads are 11 mm in diameter. The distances between tacks along the vertical edges measure 31 mm. No patent stamps were observed on the sheathing. Timber, metal and organic samples were collected for analysis.

6.2.4.3 BUF_003 sacrificial timber sheathing

This sacrificial sheathing plank's condition is fair and has one weathered and broken end. The other end, however, is a butt joint and shows the timber was tangentially converted. Since one end was broken, its original length is unknown. The preserved timber measures 3,613 mm in length, 240 mm in width and 23 mm in thickness (Figure 91). Iron nails were used to fix the plank to the outside of the hull. One square-shanked iron fastener measures 6 mm by 5.5 mm in cross-section. Its length is incomplete. No construction or tool marks were visible.

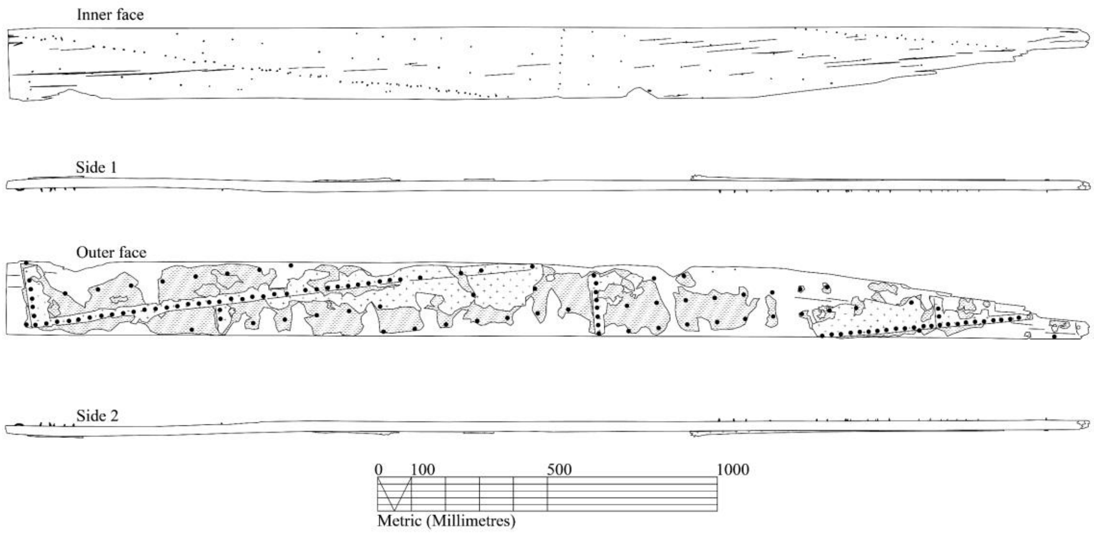

Figure 91. BUF_003 sacrificial timber sheathing fragment drawing.

Surface coverings included metal sheathing and organic resinous material. The metal sheathing measured an approximate length of 1,224 mm and 0.5 mm thick. The three sheet's widths could not be measured. The sheets overlapped by 30 mm. Sheathing tacks were also present. The shank was square in shape and the length measured 32 mm. The head of the tack measured 11.5 mm in diameter. Distances between the tacks was 34 mm. No maker's stamps were visible, although only the exposed faces were checked. Timber, metal and organic samples were collected.

6.2.4.4 BUF_004 sacrificial timber sheathing

This timber is a sacrificial outer plank and its condition is fair due to surface degradation and broken ends. Joints were therefore undiagnostic, however, the visible grain pattern suggests a tangential conversion. The timber's preserved length measured 818 mm by a preserved moulded measurement of 222 mm and a maximum 27 mm thick (Figure 92). No iron fasteners were detected or are evident in the timber. No construction marks were visible; however, tool marks were visible in the form of saw marks on the inner face of the timber.

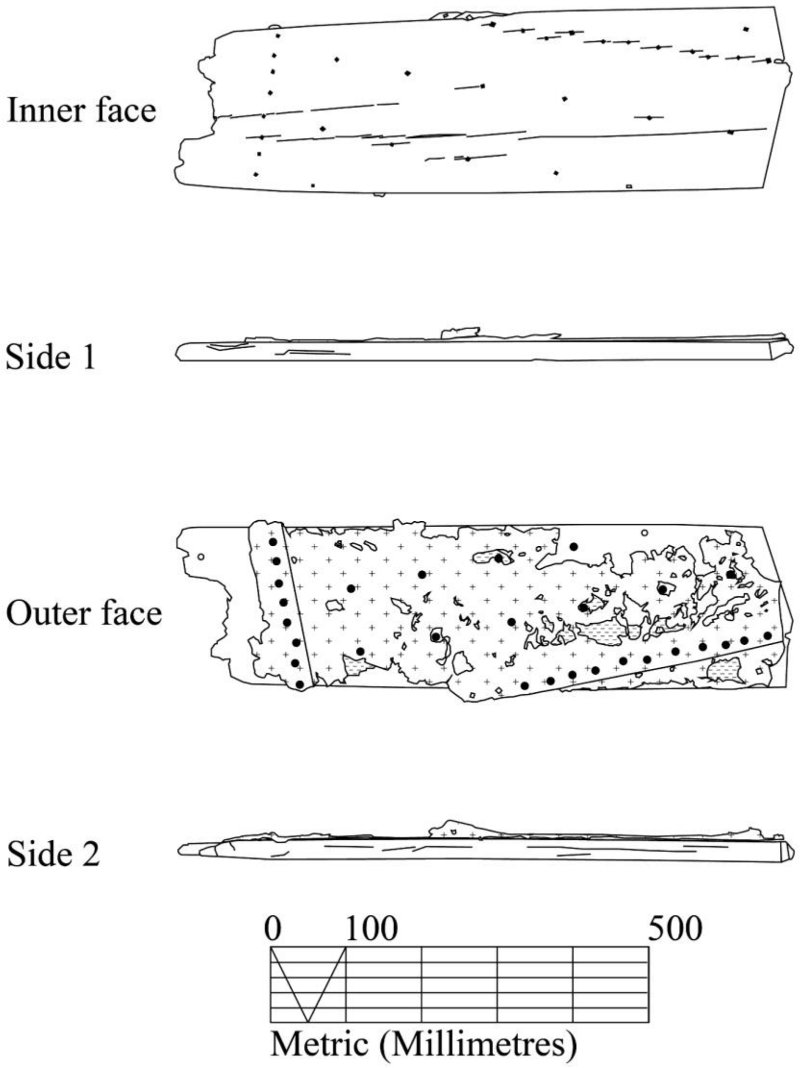

Figure 92. BUF_004 sacrificial timber sheathing fragment drawing.

Surface coverings included metal sheathing and pitch. The approximate total length of the metal sheathing sheets could not be measured due to incompleteness; however, the thickness measured 0.5 mm and the overlap between sheets measured 42 mm wide. Sheathing tacks with square shanks measured up to 32 mm long and the heads measured 11 mm across. Distances between tacks measured 33 mm apart. No maker’s stamps were visible on the sheathing. Metal and organic samples were collected. No timber sample was collected due to the condition of the timber.

6.2.4.5 BUF_005 sacrificial timber sheathing

This broken fragment of sacrificial timber planking is in poor condition. The timber conversion was undetermined and evidence of joints were undiagnostic. The preserved dimensions measured 570 mm long by 127 mm moulded and 19 mm thick (Figure 93). The magnet did not detect any ferrous metal. Possible construction and tool marks evident on the timber indicate scoring on the inner face and saw marks on the exterior face of the timber.

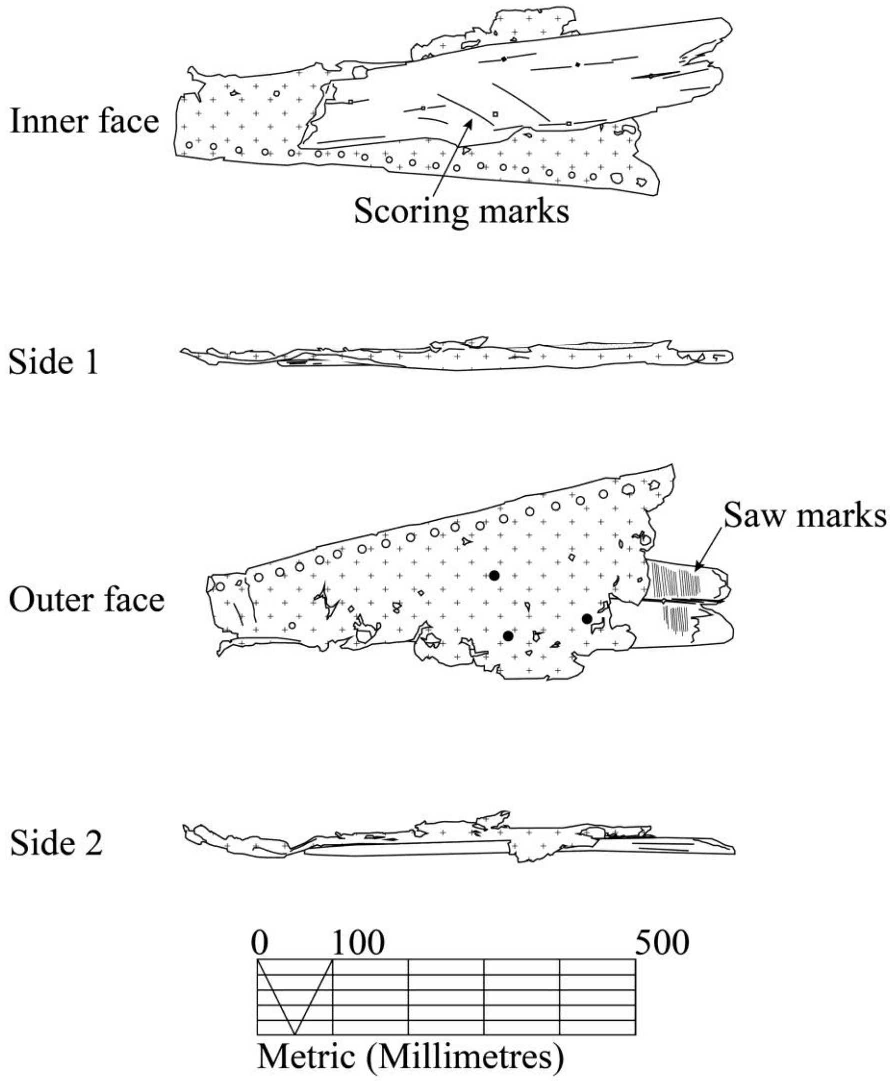

Figure 93. BUF_005 sacrificial timber sheathing fragment drawing.

The metal surface covering on the timber measured 0.5 mm thick, however, the sheet’s complete length and width could not be recorded. The horizontal overlap between the two sheets measured 27 mm wide. The distances between the tacks measured 33 mm along the perimeter. The sheathing tacks are square shanked and measured 23 mm in length. The heads of the tacks measured 11 mm in diameter. A broad arrow is visible on the underside of one of the sheathing tacks and several additional broad arrows are stamped onto what is now the underside of the metal sheathing (Figure 94). No organic material was recorded under or around the metal sheathing. Wood and metal samples were collected for analysis.

Figure 94. Broad arrow stamp recorded on BUF_005 sacrificial timber sheathing, Mercury Bay HMS *Buffalo* timber collection.

6.2.4.6 BUF_006 sacrificial timber sheathing

The sacrificial plank's condition is fair due to the level of shell concretion on the timber and its broken ends. Irrespective of the broken ends, the grain of the timber indicated the conversion as tangential. The timber measured preserved dimensions of 1,194 mm long, 123 mm moulded and a maximum 25 mm thick (Figure 95). A square fastener hole measuring 15 mm by 16 mm with iron staining is located within the concretion. The hole does not continue into the wood and suggests the fastener was loose when it became infused in the concretion. The fastener no longer exists. No construction or tool marks were visible on the timber.

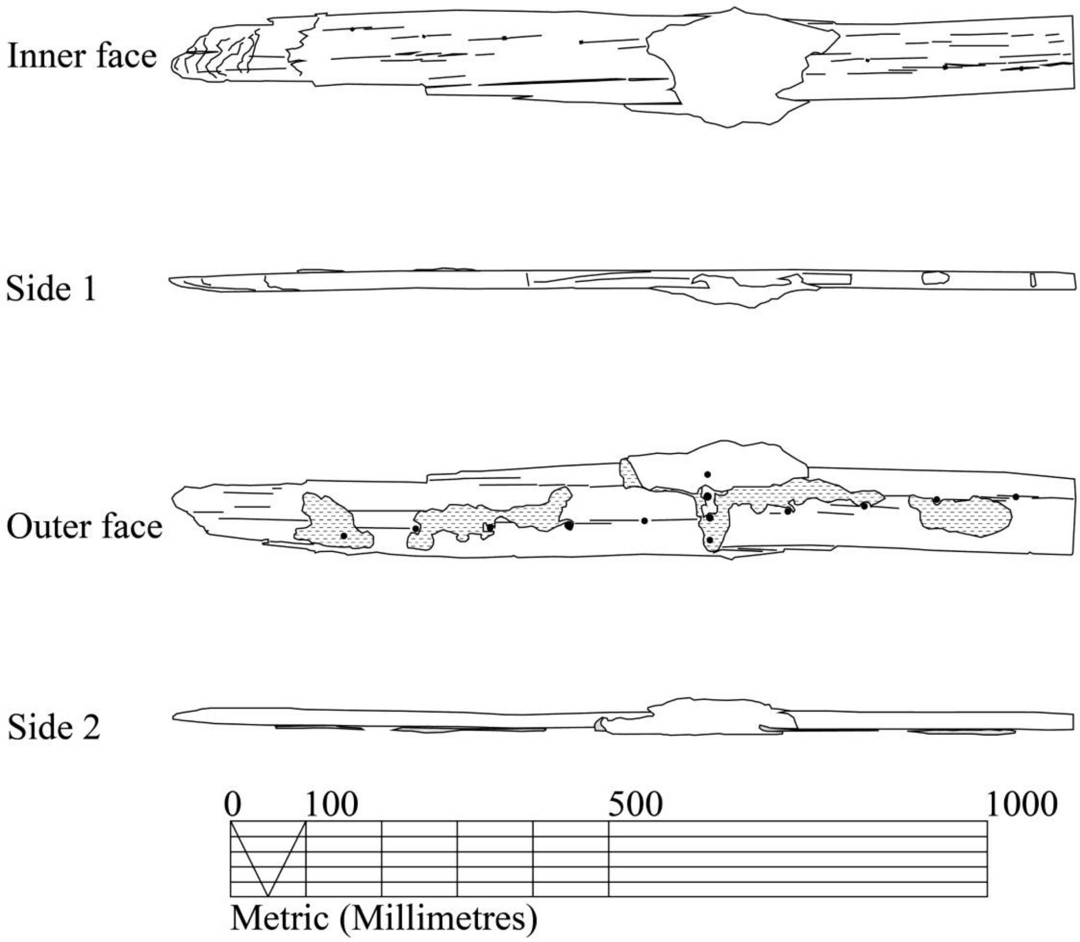

Figure 95. BUF_006 sacrificial timber sheathing fragment drawing.

The surface coverings on the timber include metal sheathing and organic material. The total dimensions of the sheathing could not be measured because it was only fragmentary remains, however, the thicknesses measured 0.5 mm. The lengths between the sheathing tack heads and tips measured approximately 23 mm. The diameters of the tack heads measured 11 mm and distances between tacks positioning measured 28 mm. No maker's stamps were visible. The timber was not sampled due to the condition of the materials and the possibility of damaging the aesthetics for museum display.

6.2.4.7 BUF_007 sacrificial timber sheathing

The condition of this sacrificial plank is fair with both ends broken. The plank was converted tangentially from the parent tree. The preserved dimensions measure 1,840 mm long and 228 mm moulded (Figure 96). The maximum plank thickness measured 25 mm. The magnet detected the presence of ferrous metal; however, no extant metal exists. The hole of a possible iron fastener measured 4 mm by 4 mm square. No construction marks were visible. Tool marks were recorded as possible saw marks.

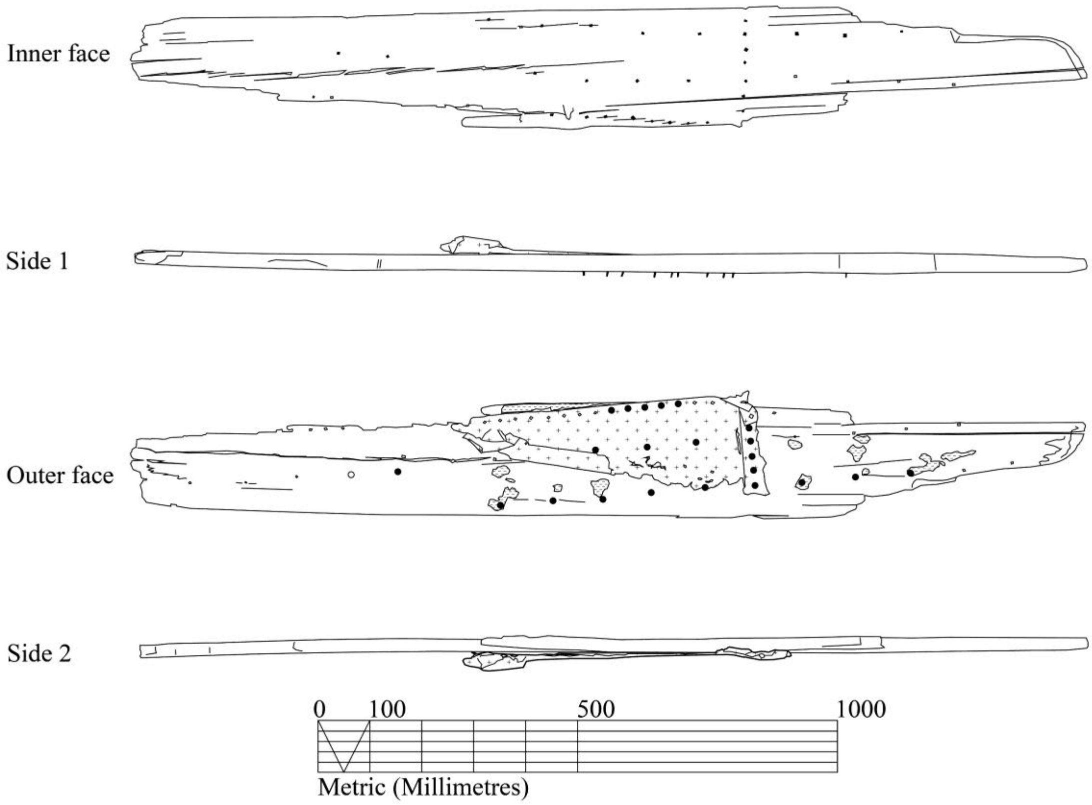

Figure 96. BUF_007 sacrificial timber sheathing fragment drawing.

Surface coverings recorded on the plank include metal sheathing and an organic layer. The maximum dimensions of the metal sheathing could not be measured due to the incompleteness of the metal sheets. The thicknesses, however, measured 0.5 mm and the overlap between two possible sheets measured 37 mm. The sheathing tack shanks are square and measure 29 mm in length with a head diameter of 12 mm. Approximate distances between the tacks measured c.30 mm. A broad arrow stamp was recorded on the underside of the sheathing. Wood, metal and organic samples were collected for analysis.

6.2.4.8 BUF_009 sacrificial timber sheathing

This sacrificial plank is in a poor state of preservation. As a result of this degradation, the conversion of the wood was not determined. Timber joints were undiagnostic and could not be identified. The preserved dimensions measured 618 mm in length, 184 mm moulded and 21 mm thick (Figure 97). The magnet detected the presence of ferrous metal in the form of a fastener. The heavily corroded fastener is square in shape and measured 4 mm by 5 mm. No construction marks were visible on the timber's surfaces, however, there is evidence of tool marks in the form of adze workings on the outer face. Variable widths between each tool mark measured between 55 mm and 75 mm.

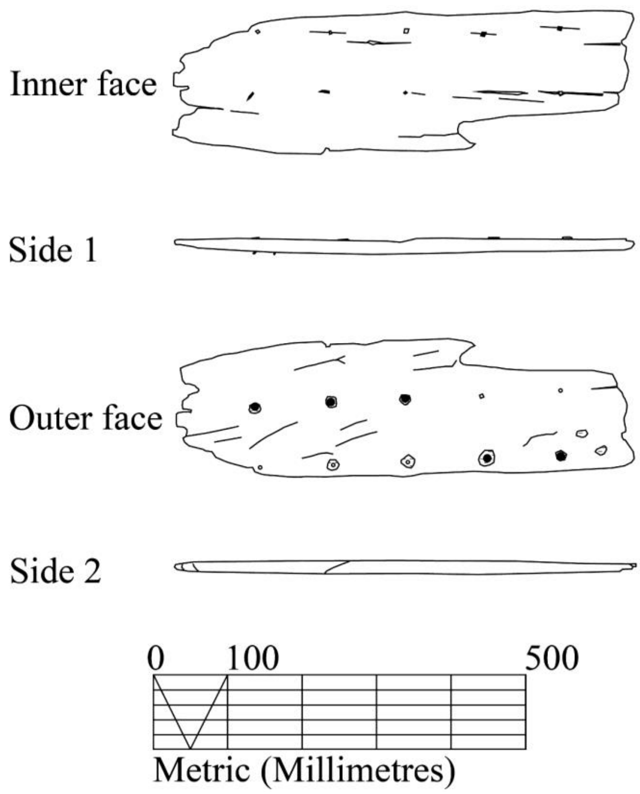

Figure 97. BUF_009 sacrificial timber sheathing fragment drawing.

Surface coverings were evident in the form of a pitch substance. This substance remained around the heads of the sheathing tacks. No metal sheathing was attached to the timber; however, the presence of sheathing tacks suggests metal sheathing was once present. The square shanked tacks measured 31 mm long. The tack head measured approximately 9 mm in diameter. Distances between the tacks' positioning was not measured due to inconsistency in extant tacks. No maker's stamps were visible. No samples were collected due to the possibility of further degrading the condition of the plank and aesthetics for museum display.

6.2.5 Timber knee

6.2.5.1 BUF_013 timber knee

This timber, recorded as a timber knee, measured 930 mm long, 90 mm moulded and 85 mm sided (Figure 98). The condition of the timber is fair with weathering and surface degradation. The entire length of the knee appears to be formed out of one piece of timber following a natural crooked branch. Where the knee curves, an additional piece of timber has been fastened to the hull side of the timber to increase the volume forming the elbow. The knee contains round ferrous metal fasteners measuring 15 mm in diameter. These probably fastened the timber to the side of the ship. This timber feature did not contain any surface coverings or display any tool marks. A timber sample was collected for wood identification.

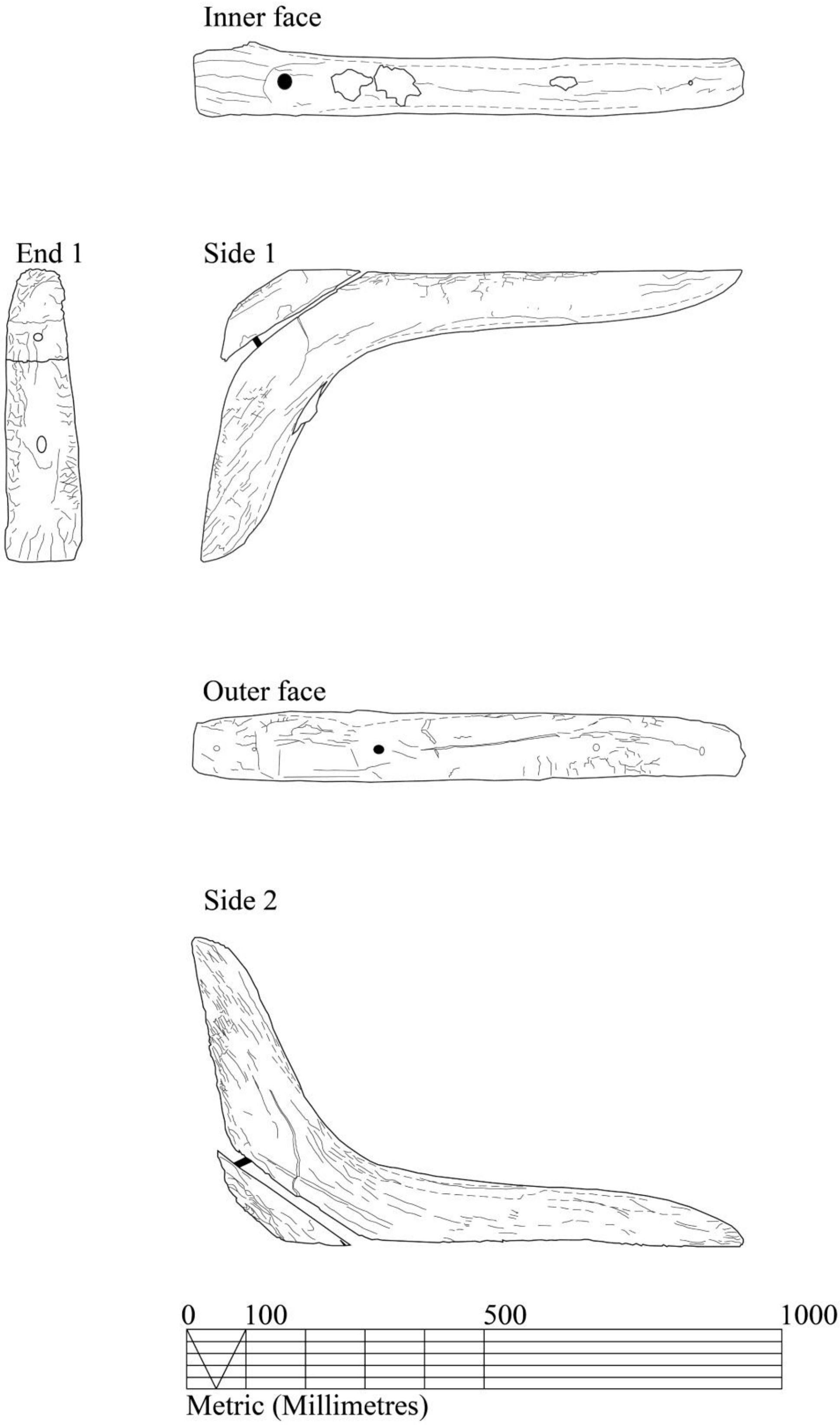

Figure 98. BUF_013 timber knee drawing.

6.2.6 Unidentified

6.2.6.1 BUF_008 unidentified timber

The function of this fragmentary piece of timber could not be determined. It is possible it is a ceiling or outer plank. The condition of the timber is poor, being damaged by marine borers. Due to the condition of the timber and not being able to identify any diagnostic features, only basic measurements and photographs were taken. The preserved dimensions were measured as 345 mm long, 175 mm moulded and 80 mm sided. The manufacturing conversion of the timber and any evidence of possible timber joints could not be determined. Evidence of a fastener was recorded as a possible treenail hole that measured 34 mm in diameter, however, no treenail was present. No iron was detected with the magnet. The timber did not display any evidence of surface coverings. No construction marks or tool marks were visible on the timber. No samples were collected.

6.2.6.2 BUF_010 unidentified timber

This fragmentary piece of timber was poorly preserved. As a result, function and timber joints could not be identified. The timber measured 709 mm long, 89 mm moulded and 41 mm sided as preserved dimensions. It is probable that iron fasteners once existed in the timber as the magnet detected ferrous metal around square holes. Two square holes measured 10 mm by 10 mm, however, no extant fasteners remained. No surface coverings were visible; therefore, no maker’s stamps could be observed. No construction or tool marks were recorded on the timber. No samples were collected for analysis due to the condition of the fragment. In addition to the basic measurements, photographs were taken to record the timber.

6.2.6.3 BUF_012 unidentified timber

This timber fragment has no diagnostic features to determine its function. The condition of the timber is poor with broken ends and degraded faces. The timber measured preserved dimensions of 635 mm long by 148 mm moulded and 107 mm sided. There is one round hole measuring 25 mm in diameter. The magnet did not detect any ferrous metal on the timber. No surface covering material associated with antifouling technologies was present. No construction or tool marks were present on the timber faces. No samples were collected because of the condition of the timber.

6.2.7 Wood identification

Wood samples were collected for identification, although only after consultation with the Museum manager and only if removing material was deemed not to affect the current state of preservation or the visual aesthetics for future museum display. Therefore, nine samples were collected from the 15 recorded timbers. These are summarised below in Table 14.

Table 14. Timber identification for HMS *Buffalo* ship timbers.

Artefact #	**Accession #**	**Scientific name**	**Common name**	**Feature**
BUF_001	2019.001.01	*Cedrus* ssp.?	Cedar	Possible plank
BUF_002	2019.002.01	*Cedrus* ssp.?	Cedar	Possible plank
BUF_003	2019.005.01	*Cedrus* ssp.?	Cedar	Possible plank
BUF_004	1980.016	Not sampled	Not sampled	Possible plank
BUF_005	1984.004	*Pinus* spp.?	Pine	Possible plank
BUF_006	2019.003	Not sampled	Not sampled	Sacrificial sheathing
BUF_007	2019.004	*Cedrus* ssp.?	Cedar	Possible plank
BUF_008	1980.016	Not sampled	Not sampled	Undetermined
BUF_009	None	Not sampled	Not sampled	Sacrificial sheathing
BUF_010	3258	Not sampled	Not sampled	Undetermined
BUF_011	1996	*Tectona* grandis	Teak	Possible plank
BUF_012	865	Not sampled	Not sampled	Undetermined
BUF_013	230313/8	*Shorea* robusta	Sal	Knee
BUF_014	31895/10	*Tectona* grandis	Teak	False keel
BUF_015	None	*Quercus* spp.?	Oak	Futtock

6.2.8 Metal analysis

It was decided by the investigator and the metal expert assisting with this study that three samples would be analysed to reflect a representative sample set of the total seven metal samples collected. These sheathing samples are used to understand the metal composition and the differences in the technology between the three case studies. The collected samples for analysis are summarised in Table 15 and the results from the analysis are presented in Table 16.

Table 15. Metal samples collected from the Mercury Bay Museum ship timber collection.

Museum sample number	**Analysis sample number**	**Description**
BUF001_M1	BUF_1M1_CS	HMS *Buffalo*'s hull sheathing
BUF002_M1	BUF_2M1_CS	HMS *Buffalo*'s hull sheathing
BUF003_M1	BUF_3M1_CS	HMS *Buffalo*'s hull sheathing

Table 16. HMS *Buffalo* sheathing elemental composition results.

	Wt%				Atomic %		
Description	**C**	**Cu**	**Total**		**C**	**Cu**	**Total**
BUF_1M1: spectrum 1	16.15	83.85	100		50.46	49.54	100
BUF_1M1: spectrum 2	14.07	85.93	100		46.41	53.59	100
BUF_1M1: spectrum 3	17.54	82.46	100		52.95	47.05	100
BUF_2M1: spectrum 1	18.23	81.78	100		54.11	45.89	100
BUF_2M1: spectrum 2	19.67	80.33	100		56.44	43.56	100
BUF_2M1: spectrum 3	16.89	83.11	100		51.81	48.19	100
BUF_3M1: spectrum 1	18.78	81.22	100		55.03	44.97	100
BUF_3M1: spectrum 2	17.66	82.34	100		53.15	46.85	100
BUF_3M1: spectrum 3	19.53	80.47	100		56.22	43.78	100

The analysis of the sheathing fragments confirms HMS *Buffalo*'s hull was covered with copper sheets. Copper weight percentages vary between 80.34 per cent and 85.93 per cent. The copper is pure with little to no inclusions of lead, but does include carbon, varying from 14.07 per cent to 19.66 per cent. These results will be discussed alongside the other three case studies.

6.2.9 Metal stamps

The following section describes disarticulated pieces of metal sheathing that were not attached to any other material. Table 17 summarises the pieces of sheathing sampled and those that display maker's marks or stamps. This is followed by detailed descriptions of the sheathing which showed diagnostic features. These descriptions are in addition to the sheathing attached to the recorded timbers described previously.

Table 17. Sheathing summary.

Artefact #	Feature	Accession #	Stamps	Sampled	Description
001	False keel sheathing	31895/10	No	Yes	-
002	Sheathing	-	No	No	-
003	Sheathing	-	No	No	-
004	Sheathing	-	No	No	-
005	Sheathing	-	No	No	-
006	Sheathing	51299	No	No	-
007	Sheathing	-	No	No	-
008	Sheathing	-	Yes	No	‘40’ and ‘MUN’
009	Sheathing	31895/10	Yes	No	‘Po 28’ and broad arrows
010	Sheathing	-	Yes	No	Broad arrows, ‘28’, ‘Po 32’ and an oval stamp containing a ‘broad arrow’ and a ‘C’ on top, ‘FE’ in the centre and ‘183…’ along the bottom.
011	Sheathing	8693/2	Yes	No	An oval stamp containing a ‘broad arrow’ and a ‘C’ on top, ‘FE’ in the centre and ‘183…’ along the bottom.

Sheathing 008 resembled a twisted weathered piece of metal sheathing. The material measured 320 mm long, 110 mm wide and c.1 mm thick. A sheathing tack was present but could not be accurately measured due to being embedded in the twists of the metal. A maker’s stamp, likely to be a Muntz metal stamp was recorded in one of the folds of the sheathing. The stamp showed the number ‘40’ and ‘MUN’ following a circular outline around the epicentre (Figure 99). The context of the sheathing is unknown and museum documentation is missing in relation to the object’s provenance, although notes suggest the material is from the HMS *Buffalo* wreck. It is improbable, however, that this piece of sheathing was used on HMS *Buffalo* considering Muntz metal eventually gained wider acceptance in the late 1830s to early 1840s. On the other hand, it is possible a Muntz metal sheet was used as a repair. Additionally, the sheet’s colour is distinctly different from the other recorded sheets, being an oxidised-green colour compared to the other sheets’ red lustre.

Sheathing 009 measured 230 mm long by 200 mm wide and approximately 1 mm thick. The piece of sheathing had a square edge showing an original corner while the other edges have been torn, possibly from the original metal sheet. No sheathing tacks were extant; however, holes exist indicating tacks had once been used to fasten the sheet to the ship’s hull. Different stamps were observed on the sheet and showed a ‘Po 28’ and several broad arrows arranged in a uniformed alternating pattern (Figure 99).

Sheathing 010 measured 430 mm long by 350 mm wide with an approximate thickness of 1 mm. The sheathing had two original edges with the other two edges being torn from the original metal. Sheathing tack holes exist in the metal, however there are no tacks present. A range of stamps are evident on the sheathing. These include broad arrows stamped in an alternating pattern, the number ‘28’, the coding ‘Po 32’ and an oval stamp encircling a ‘broad arrow’ and ‘C’ on top, ‘FE’ in the centre and ‘183…’ on the bottom (Figure 99). It is possible the bottom number resembles the year 1833. The distances between the arrows stamped measured 80 mm and each arrow points in the same direction.

Sheathing 011 measured 495 mm long by 270 mm wide and approximately 1 mm thick. The sheathing piece is ripped and torn along three edges with the fourth edge being original and displaying sheathing tack holes. No sheathing tacks were present, but the holes show a similar pattern to sheathing artefact 010. A single circular stamp was recorded and is similar to the stamp marking observed on sheathing 010. The circular stamp shows a ‘broad arrow’ and ‘C’ on top, ‘FE’ in the centre and ‘183…’ on the bottom (Figure 99). It is possible this bottom number represents the number 1833.

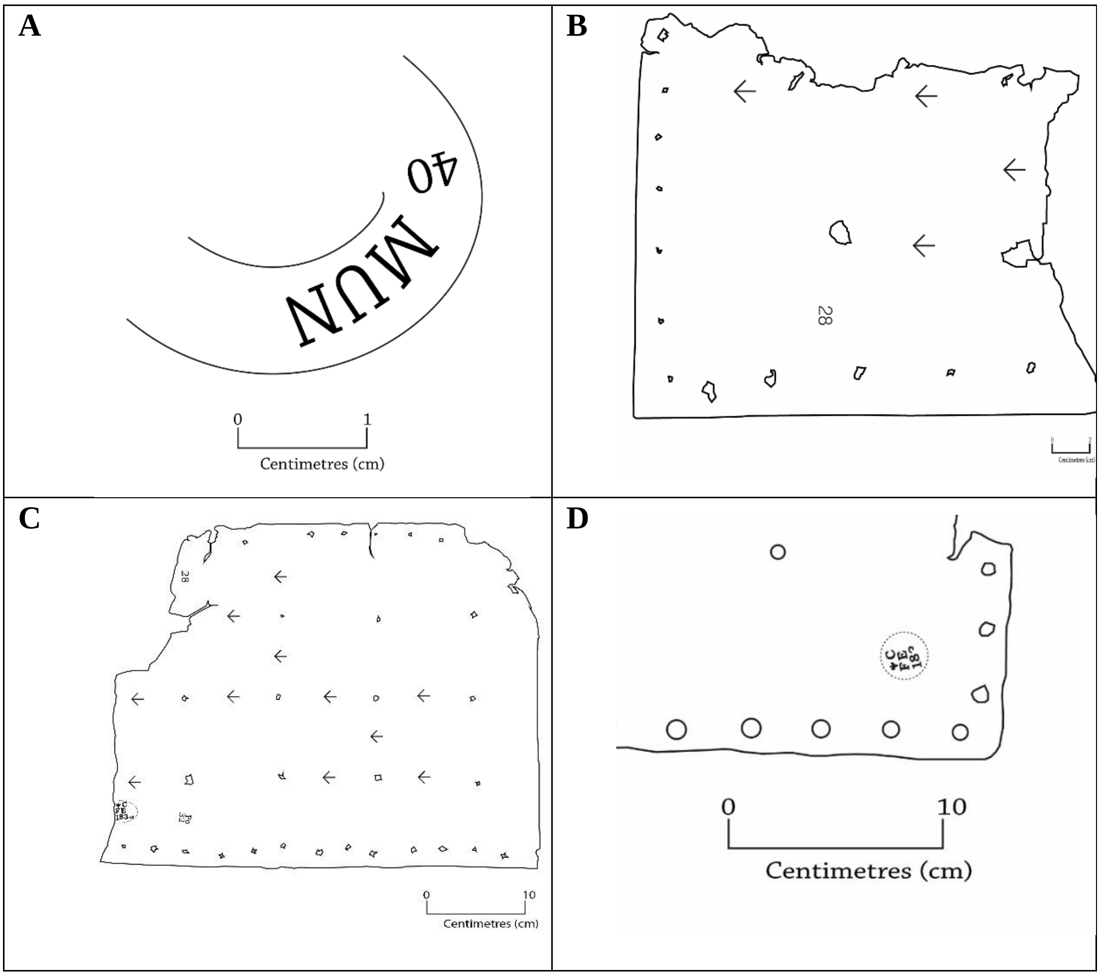

Figure 99. (A) *Buffalo* sheathing stamp 008, (B) *Buffalo* sheathing stamp 009, (C) *Buffalo* sheathing stamp 010, (D) *Buffalo* sheathing stamp 011.

6.2.10 Organic analysis

Five timbers (BUF 001, BUF 002, BUF 003, BUF004 and BUF 007) had pitch-like substance remains. These timbers were identified as sacrificial timber planks and contained a pitch-like layer between the timber and metal sheathing. All five samples returned successful results and are presented in Table 18.

Table 18. Pitch results from HMS *Buffalo* timbers.

Sample	Compound	Retention time (minutes)
BUF 001	TMS derived aniline	15.3
	Trimethyl pyridine	16.1
	TMS derived p-coumaric acid	19.6
	Methenamine	19.7
	Dodecanoic acid	25.1
	TMS derived myristic acid	27.2
	Hexadecanoic acid, methyl ester	27.9
	TMS derived palmitic acid	29.1
	TMS derived stearic acid	31.3
BUF 002	Methoxy phenyl oxime	14.6
	7-methoxy-4-quinolinol	15.2
	TMS derived aniline	15.3
	1,2,3,4-tetrahydroisoquinoline 6,7,8-trimethoxy-1,2-dimethyl	16.9
	TMS derived 4-tertybutyl aniline	17.2
	TMS derived arsenous acid	17.3
	TMS derived p-coumaric acid	19.6
	Methenamine	19.7
	TMS derived palmitic acid	29.1
BUF 003	Methoxy phenyl oxime	14.6
	7-methoxy-4-quinolinol	15.2
	TMS derived arsenous acid	15.7
	TMS derived p-coumaric acid	19.6
	Methenamine	19.7
	Acetaphthylene	22.9
	Anthracene	26.9
	TMS derived palmitic acid	29.1
	Pyrene	30.2
	TMS derived stearic acid	31.3
	8-isopropyl-1,3-dimethylphenanthrene	32.8
	TMS derived dehydroabietic acid	33.3
BUF 004	Methoxy phenyl oxime	14.5
	TMS derived arsenous acid	15.7
	Napthalene	19.1
	TMS derived p-coumaric acid	19.6
	Acetaphthylene	22.8
	Anthracene	26.9
	TMS derived palmitic acid	29.1
	Cyclic sulfur	29.6
	Fluoranthene	29.7
	Pyrene	30.3
	TMS derived stearic acid	31.3
	Chrysene	34.1
	Triphenylene	34.2
BUF 007	Methoxy phenyl oxime	14.6
	TMS derived 2-amino-tertbutylphenol	15.2
	Benzene-1-propynyl	16.9
	Napthalene	19.1
	TMS derived p-coumaric acid	19.6
	methenamine	19.7
	Acetaphthylene	22.9

	Phenanthrene	26.8
	Anthracene	26.9
	Acridine	27.1
	Anthracene, 1-methyl	28.1
	Napthene, 2-phenyl	28.7
	TMS derived palmitic acid	29.1
	Fluoranthene	29.7
	Pyrene	30.3
	11H-benzo[a]fluoren-11-one	33.2
	Benzo[b]naphtho[1,2-d]thiophene	33.5
	Benzo[c]phenanthrene	33.6
	Triphenylene	34.1
	Chrysene	34.2
	Chrysene-5-methyl	35.1
	Benzo[k]fluoranthene	36.4

6.2.11 Previous archaeology

In April 1986, the Department of Environment and Planning, South Australia, lead a site assessment and partial excavation of the HMS *Buffalo* wreck site in Whitianga, Aotearoa New Zealand. At the time of excavation, the field team described the site as partially uncovered showing large amounts of iron ballast. In addition, frames were exposed extending up to 500 mm from the sea floor and followed the ship's outline. Ship structure recorded during the 1986 field season is summarised below (Table 19).

Table 19. The results from the 1986 excavation.

Material	**Length (mm)**	**Width (mm)**	**Depth (mm)**	**Excavation grid**	**Notes**
Timber	100	40	60	2	None
Planking	540	105	25	2	None
Planking	390	7	25	3	None
Planking	280	55	25	3	None
Planking	310	30	25	3	None
Planking	520	70	25	3	Nail markings along the edge
Timber	200	45	50	1c	None
Timber	270	170	50	1c	Square nail hole 18 mm^2 and a thin iron concretion
Timber	270	110	70	1c	Possible deck cleat
2 x small pieces of copper sheathing	120	30	2	1d	None
Timber	180			1d	30 mm diameter

Detailed measurements and descriptions, however, were not provided in the preliminary report on the survey. A final report was intended to be filed with the

Historic Places Trust, but this never eventuated (Bill Jeffery pers. comm. 2017). This leaves the above measurements as the only known in situ archaeological recording of the *Buffalo* shipwreck.

6.3 Summary

The timbers recorded for HMS *Buffalo* provide archaeological evidence of ship timbers located around the keel and bilges. A total of 15 timbers were recorded in the Mercury Bay Museum’s HMS *Buffalo* collection. None of the timbers had complete lengths as they were either broken or have been cut. Three timbers presented maximum moulded measurements and two presented maximum sided dimensions. The timbers recorded include a false keel fragment, sacrificial sheathing planks, a possible futtock and a possible timber knee. Wood identification shows the ship utilised several different genera of wood, including teak, oak and cedar and/or pine. Material analyses confirm the hull was sheathed in copper sheets with a layer of pitch between the sheets and sacrificial timber planks. No fibres were extant for recording.

Chapter 7. *Edwin Fox* results

7.1 Historical findings and hull design

Edwin Fox is a historically preserved ship's hull that allows ship components to be recorded in context. The recorded timbers were easily identified and labelled accordingly. Therefore, this section presents the timbers based on their known functions within the ship's hull. *Edwin Fox* includes additional headings linked to other investigations to understand its hull assembly. Dendrochronology was only performed on the *Edwin Fox* hull and the results are included with wood identification. Hull lines produced from the laser scanning are also presented, followed by hull coefficients calculations.

Dimensions for *Edwin Fox* are summarised below in Table 20. This information has been extracted from Nigel Costley's (2014) book, *Teak and Tide: The Ebbs and Eddies of the Edwin Fox*, which includes extensive historical research about *Edwin Fox*. In addition, the researcher visited the National Archives in London and reviewed ships' registries for *Edwin Fox* to confirm measurements. Notably, the registered tonnage is 835 tons (the National Archives CUST 130/49), compared to other contemporary published sources of 891 ¾ tons.

Table 20. Scantlings as historically recorded for *Edwin Fox*.

Description	Metres	Feet	Inches	Tons
Length overall	47.85	157	-	
Keel length for tonnage	43.91	144	8/10	
Extreme breadth	8.85	29	8/10	
Depth of hold	7.02	23	6/10	
Tonnage by measurement				835

7.1.1 Hull lines

In December 2016, the hull of *Edwin Fox* was scanned by laser. This produced a 3D digital model of the vessel's hull in its current state. Using this model, the measured ship's lines were then re-drawn using DELFTship software (Figure 100). The ship hull lines show the vessel is box-like in shape and has a relatively square bilge. The bow has a slightly raking stem. Other observations of the lines indicate slight warping in the ship's hull and hogging along the keel. Furthermore, when compared with the other two primary case studies, these ships lines will be used to discuss the shape of the hull over time. The lines are produced directly from the laser scan data. Thus, the hull lines are not faired.

7.1.2 Hull coefficients

Using the lines plans, *Edwin Fox*'s structure parameters were used to calculate the hull coefficients. The block coefficient is 0.5847, the prismatic coefficient is 0.7018 and the midship coefficient is 0.8332. These coefficients are discussed along with the those of the other two primary case studies to assess change in hull shape over time.

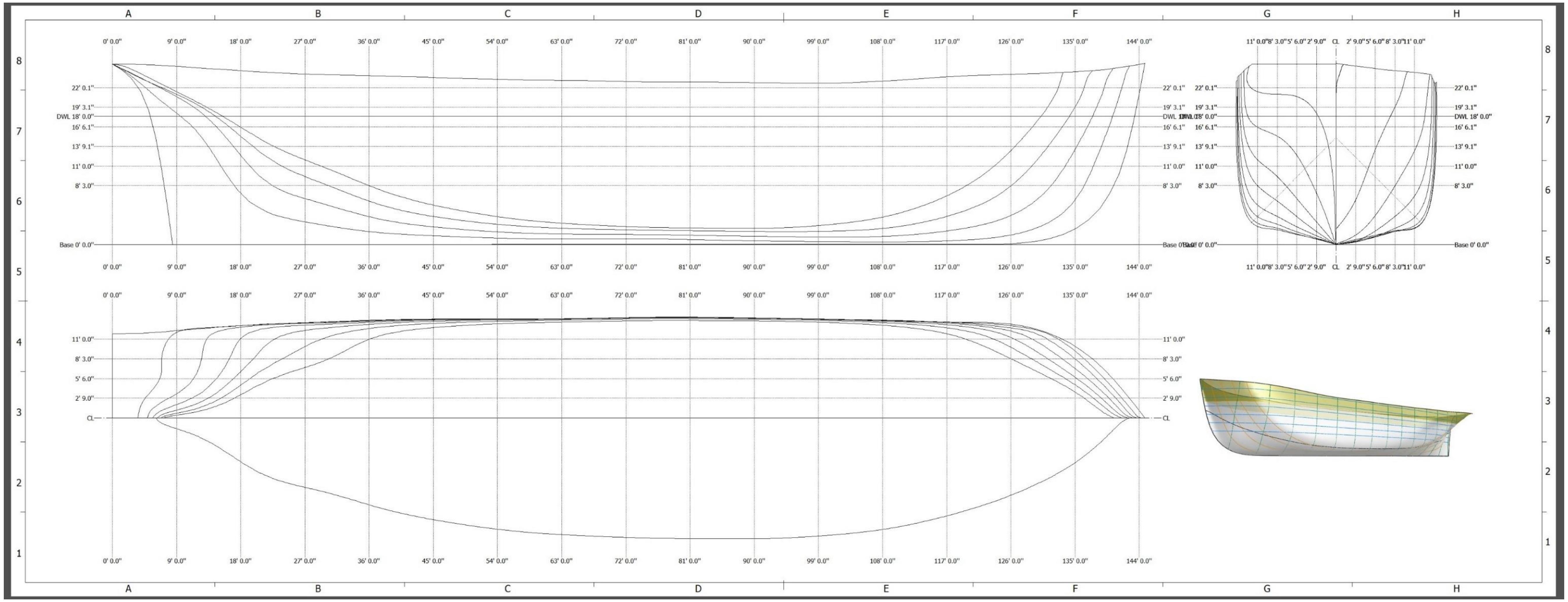

Figure 100. *Edwin Fox* ship's lines plan.

7.2 Midship cross-section

In April 2017, on-site fieldwork produced the data for a cross-section drawing of midships. The drawing was completed in January 2018, with the inclusion of a few missing topside deck planks. The resulting cross-sectional drawing illustrates components used in the assembly of the ship's hull (Figure 101). The drawing shows the hull as it was recorded in 2017 and 2018. Thus, the timbers appear warped in shape and not flush, as they would have been when the ship was newly constructed. Each numbered timber correlates with the corresponding timber catalogue.

The cross-section highlights different constructional elements. It shows the hull is double planked, with the outer diagonal layer abutting three longitudinal planks positioned parallel with the keel. Both the garboard strake and the second outer layer longitudinal plank are recessed into the rabbet along the keel. There is evidence of a false keel attached to other places of the keel, although only the keel remained at midships for recording. Individual futtocks could not be determined because the structure was not accessible for measuring. This would have required removing several ceiling planks, an intrusion that was not permitted by museum staff. Floor timbers are placed between the keel and keelson and adjoin the ends of the futtocks. A keelson sits on top of the floor timbers and runs longitudinally along the centre of the hull from bow to stern. A rider keelson is positioned on top of the keelson between the forward and main masts. There is evidence at midships that a stanchion was placed on top of the rider keelson although it no longer exists. The stanchions were fixed to the rider keelson with a mortise and tenon joint. The limber strakes sit parallel with the first keel and allow for placement of a limber board. The ceiling planks continue longitudinally from bow to stern up the side of the hull towards the gunwales. After four ceiling planks, two bilge keelsons are placed symmetrically on both the port and starboard sides. Both support hold stanchions and use the same mortise and tenon joint as found on the centre rider keelson. The stanchions stand vertical to act as supports for the deck beams above. Ceiling planking continues up the sides of the hull on a longitudinal axis fore and aft. At the turn of the bilge are sets of three thick ceiling strakes on both the port and starboard sides. Shelf clamps exist on both the port and starboard sides directly below the decking beams. In addition to these ceiling planks are the added diagonal metal bracings. These bracings are installed on the undersides of the deck beams and extend diagonally down towards the bilge. The first deck beam extends the internal beam length of the hull and supports longitudinal deck planking and waterways. On the beam which is recorded at midships is also part of a hatch and provides evidence of hatch combings. Ceiling planking then continues up the internal sides of the hull in various states of preservation. The top deck cross beams have been cut and no longer exist in their original state. However, it is evident where this beam was connected and how it was supported in relation to the hull. On the outside of the hull, evidence of two longitudinal sheer strakes start from the top of the exposed futtocks on the port side. The starboard side equivalent no longer exists for recording. Below these strakes, a single layer of outer topside hull planking, smaller in size than the hull planking below the water line, extends from the current height of the sheer strakes down to the wale. The wale is large enough to abut the first layer of outer bottom planking and is recessed to abut the second layer of diagonal timber planking. Finally, although too small to depict on the illustration, a layer of Muntz metal sheathing is attached to the outer layer of bottom planking and the keel.

A longitudinal construction plan of *Edwin Fox*’s hull was drawn from the data collected during the laser scanning (Figure 102). The plan allowed for the midship recorded structure to be highlighted. This presents a different perspective to understand longitudinally how these components have been placed within the ship’s hull. Furthermore, it provides context to the hull description above, as well as for the timber components that are described later in this chapter.

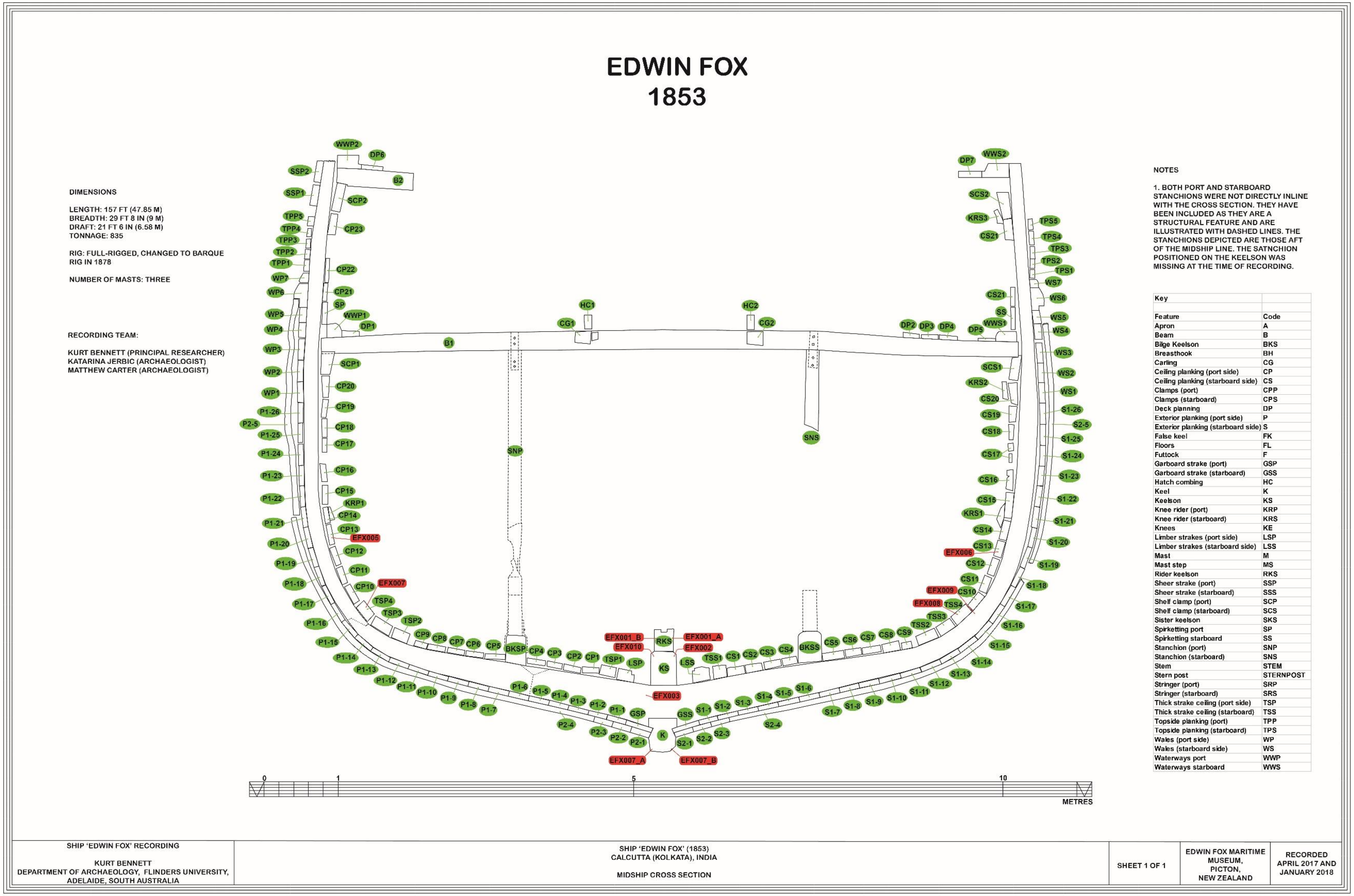

Figure 101. *Edwin Fox* midship cross-section labelled with timber components.

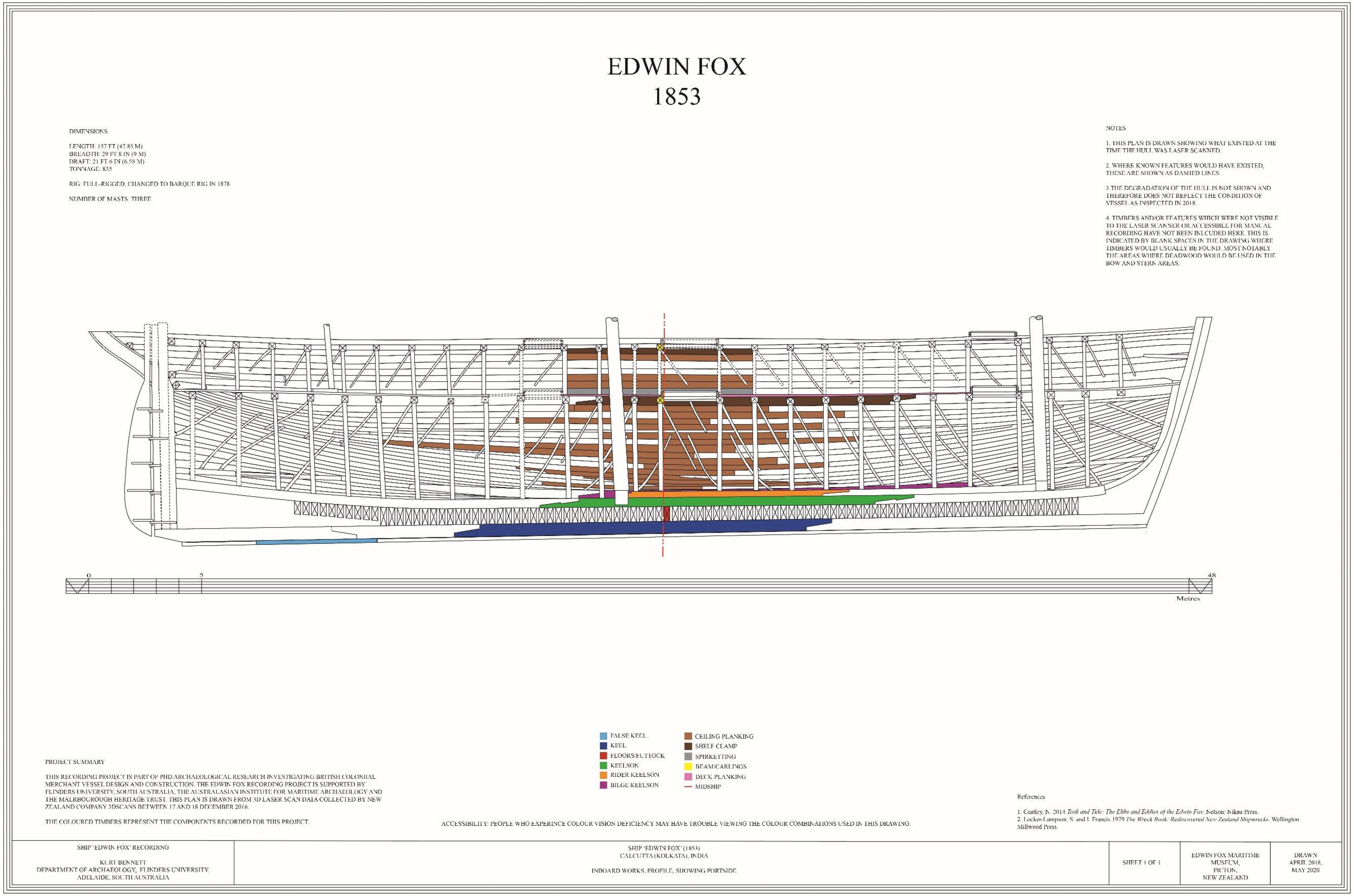

Figure 102. Longitudinal cross-section showing the port side and internally recorded timbers.

7.2.1 Timbers

The ship components described in this chapter were selected due to their comparable qualities with the recorded *Endeavour* and HMS *Buffalo* hull timbers. The timber data presented here is from *Edwin Fox*'s midship section and reflects a representative sample of the ship. Additional data that is not comparable with the other vessels for this study is available on the *Edwin Fox* timber catalogue. Timber identification, dimensions, fasteners and construction evidence are presented in the following sections.

7.2.1.1 False keel

A broken section of the false keel (FK) exists in context with the keel (Figure 103). The location of the false keel was not directly at midships but is included in the recording because the other two case studies have recorded false keels. The aft end of the section of timber is located 3.31 m from the stern post. The false keel measured 4,360 mm as a preserved length, with a maximum original width of 342 mm and is 115 mm thick. The forward end has evidence of a box joint which is heavily weathered. The box joint is positioned in the centre, 150 mm from the port side and measured 30 mm in width by 45 mm thick. Copper alloy fasteners located in the timber are driven from the outer face into the keel. The smaller of the bolts measured 25 mm in diameter at the head. The larger fasteners with washers measured 37.5 mm in diameter for the bolt head and 63 mm diameter for the external perimeter of the washer. These bolts probably extend further into the keel, but the lengths could not be measured. There is no evidence of staples used for securing the false keel to the main keel. No tool or construction marks were identified. Metal sheathing tacked to the false keel continues up and around the main keel. The metal sheathing was also placed between the false keel and keel and was folded at the forward end of the timber (Figure 104). The false keel was sampled for wood identification.

Figure 103. Aft section of the false keel attached to the main keel of *Edwin Fox*, facing port side.

Figure 104. Metal sheathing folded in the forward join of the false keel.

7.2.1.2 Keel

The keel (K) is preserved along the entire length of the vessel and assembled using four individual components with horizontal scarf joints. The section of keel at midships measured 15.93 m long, 345 mm moulded and 440 mm sided. The keel is in good condition with most of the degradation towards the bow and some weathering towards the sternpost. The outer garboard strake and planking still connect with the keel's rabbet. The keel includes preserved metal sheathing. Thus, identifying other construction features was not achievable without dismantling the ship and removing the metal coverings. The types and sizes of fasteners used in the keel were not determined and no tool marks or construction marks were identified. The keel was cored for dendrochronology and used for wood identification.

7.2.1.3 Floors and futtocks

The floor timber (FL) at midships remains in context and is connected to the keel, keelson and planking on either side. The timber is positioned at 90 degrees to the keel and continues on both the port and starboard sides underneath the ceiling planking. The floor timber measured a maximum 290 mm moulded and a maximum 540 mm sided. The length could not be accurately measured due to inaccessibility with adjacent futtocks and attached ceiling planking. The space between floor and futtocks measured between 80 mm and 100 mm with the adjacent futtock to the floor timber measuring 280 mm in room. The main fasteners used for securing the floor timbers to the keel and keelson could not be determined because they were not visible for recording. The fasteners used for fixing the ceiling planking to the floors are described under the ceiling planking section. An additional feature of the floor timber is a pair of watercourses shaped as half circles, measuring 60 mm as a half diameter and cut fore and aft through the timber. The watercourses are located close to the keel, which takes advantage of the lowest part of the ship to draw water to the bilge pump. Timber joints connecting the floor timber to the futtocks were not visible and as a result were not recorded. An example of a possible chock placed between a floor timber and first futtock located towards the bow was observed in the gap of two ceiling planks however, detailed recording could not be completed. No tool or construction marks were identified. The timber conversion was not positively identified although it is probably whole. The floor timber was cored for dendrochronology and the core was used to identify the wood.

7. 2.1.4 Garboard strake

Garboard strakes are present on both the port and starboard sides of the keel. The accessibility for the researcher to record these timbers was limited due to the preservation of the second layer of hull planking. The lengths could not be measured because their ends were not visible. The port side strake (GSP) measured a maximum 380 mm in width by 62 mm thick. The starboard strake (GSS) measured a maximum 380 mm in width and 65 mm thick. No tool or construction marks were visible, nor were the strakes sampled.

7. 2.1.5 Hull planking layer one

Hull planking layer one is the run of planks directly attached to the floors and futtocks. Twenty-six outer planks were recorded on both the port and starboard sides (Table 21). The port side planks (Prefix-P1) range between 260 mm and 290 mm in width and between 60 mm and 77 mm thick. The starboard side planks (Prefix-S1) range between 260 mm and 300 mm in width and between 60 mm and 80 mm thick. The lengths of the planks could not be measured because the ends are covered by the second layer of outer hull planking. In addition, fasteners, tool marks and timber joins were not visible for recording. This layer of hull planking was not sampled.

Table 21. Recorded dimensions of hull planking, layer one, *Edwin Fox*.

Port					**Starboard**			
ID	**Length**	**Width**	**Thick**		**ID**	**Length**	**Width**	**Thick**
P1-1	NM	260	60		S1-1	NM	260	60
P1-2	NM	260	60		S1-2	NM	285	60
P1-3	NM	280	60		S1-3	NM	280	60
P1-4	NM	270	60		S1-4	NM	280	60
P1-5	NM	280	65		S1-5	NM	290	60
P1-6	NM	280	70		S1-6	NM	280	60
P1-7	NM	280	70		S1-7	NM	280	70
P1-8	NM	280	60		S1-8	NM	270	60
P1-9	NM	280	65		S1-9	NM	280	78
P1-10	NM	280	60		S1-10	NM	300	70
P1-11	NM	280	60		S1-11	NM	280	65
P1-12	NM	280	60		S1-12	NM	290	65
P1-13	NM	280	60		S1-13	NM	290	70
P1-14	NM	280	60		S1-14	NM	280	70
P1-15	NM	280	60		S1-15	NM	280	70
P1-16	NM	280	60		S1-16	NM	280	75
P1-17	NM	280	60		S1-17	NM	290	70
P1-18	NM	280	65		S1-18	NM	290	70
P1-19	NM	260	75		S1-19	NM	290	60
P1-20	NM	280	65		S1-20	NM	260	70
P1-21	NM	280	60		S1-21	NM	280	80
P1-22	NM	280	60		S1-22	NM	280	78
P1-23	NM	290	60		S1-23	NM	270	80
P1-24	NM	280	70		S1-24	NM	280	80
P1-25	NM	270	60		S1-25	NM	290	80
P1-26	NM	280	77		S1-26	NM	293	80
NB: All measurements presented in millimetres (mm). NM = Not Measured.								

7. 2.1.6 Hull planking layer two

The hull planking layer two is the run of planks directly attached to ‘hull planking layer one’ and is the outer most layer of timber planking before the metal sheathing coverings (Figure 105). The second layer of hull planking that intersects the midship line includes five timbers on both the port and starboard sides. The timbers appear to have butt joints where they are fastened abutting the three longitudinal planks next to the keel. Three planks are positioned either side of the keel, bow to stern. The next run of planks are rotated vertically and fastened to the hull from the longitudinal planks to wale. The ends of the top planks (P2-5 and S2-5) are abutted to the recessed port and starboard wales. The port side planks (Prefix-P2) range between 240 mm and 260 mm in width and between 70 mm and 80 mm thick. The starboard planks (Prefix-S2) range between 240 mm and 260 mm in width and between 60 mm and 70 mm in thickness. Some lengths of planks are covered by metal sheathing and fibrous matting and remain unmeasured. The planks dimensions are summarised in Table 22. Not all planks had fasteners visible for recording. Only the planks towards the topsides of the ship where the metal sheathing had worn away had exposed fasteners. On both sides, copper alloy bolts measured 25 mm in diameter. Their lengths could not be measured. Treenails were also used for fixing this layer of planking to the ship. The treenails measured 33 mm diameter and have equilateral-triangle-wedges with some manufacturing dimensional variation. There is no evidence of tool marks. The plank directly next to the keel was sampled for wood identification.

Figure 105. The outer most layer of hull planking on *Edwin Fox*, port side, facing forward. Midships is located in the area where the planks are positioned most vertical. Red arrow indicates approx. midship line.

Table 22. Recorded dimensions of hull planking, layer two, *Edwin Fox*.

Port					Starboard			
ID	**Length**	**Width**	**Thick**		**ID**	**Length**	**Width**	**Thick**
P2-1	NM	260	80		S2-1	NM	260	60
P2-2	NM	260	78		S2-2	NM	250	60
P2-3	NM	260	70		S2-3	NM	258	60
P2-4	6390	240	80		S2-4	5700	240	70
P2-5	3000	240	80		S2-5	3900	240	70
NB: All measurements presented in millimetres (mm). NM = Not Measured.								

7.2.1.7 Ceiling planking

Ceiling planking is present below the lower deck and extends between the limber boards to the shelf clamps on both the port and starboard sides (Figure 106). The port side ceiling plank (Prefix-CP) dimensions range between 6,820 mm and 19,684 mm in length, 180 mm and 300 mm in width and 62 mm and 100 mm in thickness (Table 23). The starboard side (Prefix-CS) ceiling planks range between 7,240 mm and 20,360 mm long, 180 mm and 315 mm wide and 70 mm and 110 mm thick. Fasteners used to fix the ceiling planking include iron bolts with washers, iron dumps, copper alloy bolts with washers and treenails. The iron bolts with washers measured approximately 40 mm to 50 mm in diameter, with variation caused by corrosion product. While these iron fasteners are probably bolts with clinch rings, their complete form and length could not be inspected and recorded. The iron dumps measured c.25 mm in diameter and their exact lengths are unknown. The copper alloy bolts measured c.40 mm in diameter, including the washer, and their lengths are also unknown. Treenails used in addition to the metal fastenings varied between 30 mm and 37 mm in diameter. These treenails include two types of wedges. The straight wedges measured c.4 mm wide by the diameter of the treenail, and cross wedges similarly measured 4 mm wide by the diameter of the treenail. One treenail's loose straight wedge measured 45 mm in length. The treenails with cross-wedges were placed in the seams between two planks whereas the treenails with straight wedges were placed along the individual plank. Smaller treenails measured 25 mm in diameter with no wedges and these are probably plugs. Possible chisel and scoring marks are recorded as tool and construction markings. The patterning of the chisel marks looked irregular in location and shape. Two ceiling planks, CP13 and CS13, were sampled for dendrochronology and wood identification.

Figure 106. Ceiling planking inside the hull of *Edwin Fox*, port side, facing forward. The main mast is located to the far right.

Table 23. Recorded dimensions of the ceiling planking, below the lower deck, *Edwin Fox*.

Port					Starboard			
ID	**Length**	**Width**	**Thick**		**ID**	**Length**	**Width**	**Thick**
CP1	9090	240	90		CS1	9170	220	110
CP2	6820	240	80		CS2	7240	240	100
CP3	19684	240	80		CS3	20360	230	100
CP4	9440	240	75		CS4	11368	210	100
CP5	7240	270	79		CS5	7960	290	100
CP6	9110	240	70		CS6	9250	210	100
CP7	9110	215	65		CS7	9100	240	90
CP8	10642	240	78		CS8	11356	240	110
CP9	7240	180	80		CS9	7978	180	90
CP10	7480	240	90		CS10	7930	240	100
CP11	8330	215	80		CS11	8700	250	95
CP12	7970	245	78		CS12	12154	245	100
CP13	14220	278	69		CS13	8440	220	100
CP14	9450	210	62		CS14	8680	315	100
CP15	8770	260	78		CS15	14001	310	100
CP16	8290	240	80		CS16	14270	300	90
CP17	8370	290	70		CS17	11870	260	70
CP18	8740	250	70		CS18	12970	210	70
CP19	8200	240	78		CS19	8350	210	100
CP20	8770	300	100		CS20	8770	300	100
NB: All measurements presented in millimetres (mm). NM = Not Measured.								

Ceiling planking also extends between the upper and lower decks, running longitudinally bow to stern (Table 24). Some planks are missing and were probably removed when the ship was used for coal storage or later by contemporary salvage activity. Complete lengths of the planks were not measured because their ends were either obstructed by stored items or installed museum displays. The port side ceiling planks (CP) measured between 240 mm and 320 mm wide by 60 mm thick. The starboard side planks (CS) measured between 250 mm and 300 mm wide by 60 mm thick. Iron bolts are used to fasten the planks to the upper futtocks. The bolts measure between 35 mm and 38 mm in diameter with variation caused by different layers of corrosion. No tool marks were evident for recording. The ceiling planks were butted together. No planks on this level of the ship were sampled.

Table 24. Recorded dimensions of the ceiling planking between the upper and lower decks, *Edwin Fox*.

Port					Starboard			
ID	**Length**	**Width**	**Thick**		**ID**	**Length**	**Width**	**Thick**
CP21	NM	240	60		CS21	NM	250	60
CP22	NM	320	60		CS22	NM	300	120
CP23	NM	290	118		-	-	-	-
NB: All measurements presented in millimetres (mm). NM = Not Measured.								

7.3 Metal sheathing

A large amount of copper sheathing still covers the area below the ship's waterline. The condition is between fair and good as it shows signs of oxidation and general degradation caused by previous salvaging activities and the current hull supports (tongs). The drydock timber tongs supporting the hull show they have moved over time and have etched lines through the ships sheathing and softer parts of the outer hull timber planking (Figure 107). The sheathing itself, however, is in relatively good condition and provides evidence for the maker of the sheathing, panel positioning, materials included in the application of antifouling technologies and how the sheets are fastened to the hull. The following presents the results from the recording of sheathing on the hull of *Edwin Fox*.

Figure 107. Damage caused by tongs (support poles) (Photograph: Matt Carter, April 2017).

Sheathing panels measured 1,210 mm long, 353 mm wide and 1 mm thick. The top and bottom horizontal overlaps measured 25 mm. The right and left vertical overlaps measured between 28 and 38 mm. Each full-length panel was fastened with approximately 96 sheathing tacks, with the concentration of nails following the two ends and topside edge of the panel. Additional tacks were used to fill the sheet in a regular square pattern, three nails high by 10 nails long. Each panel of sheathing is positioned to overlap on top of the aft sheet and on the bottom side edge of each above panel (Figure 108).

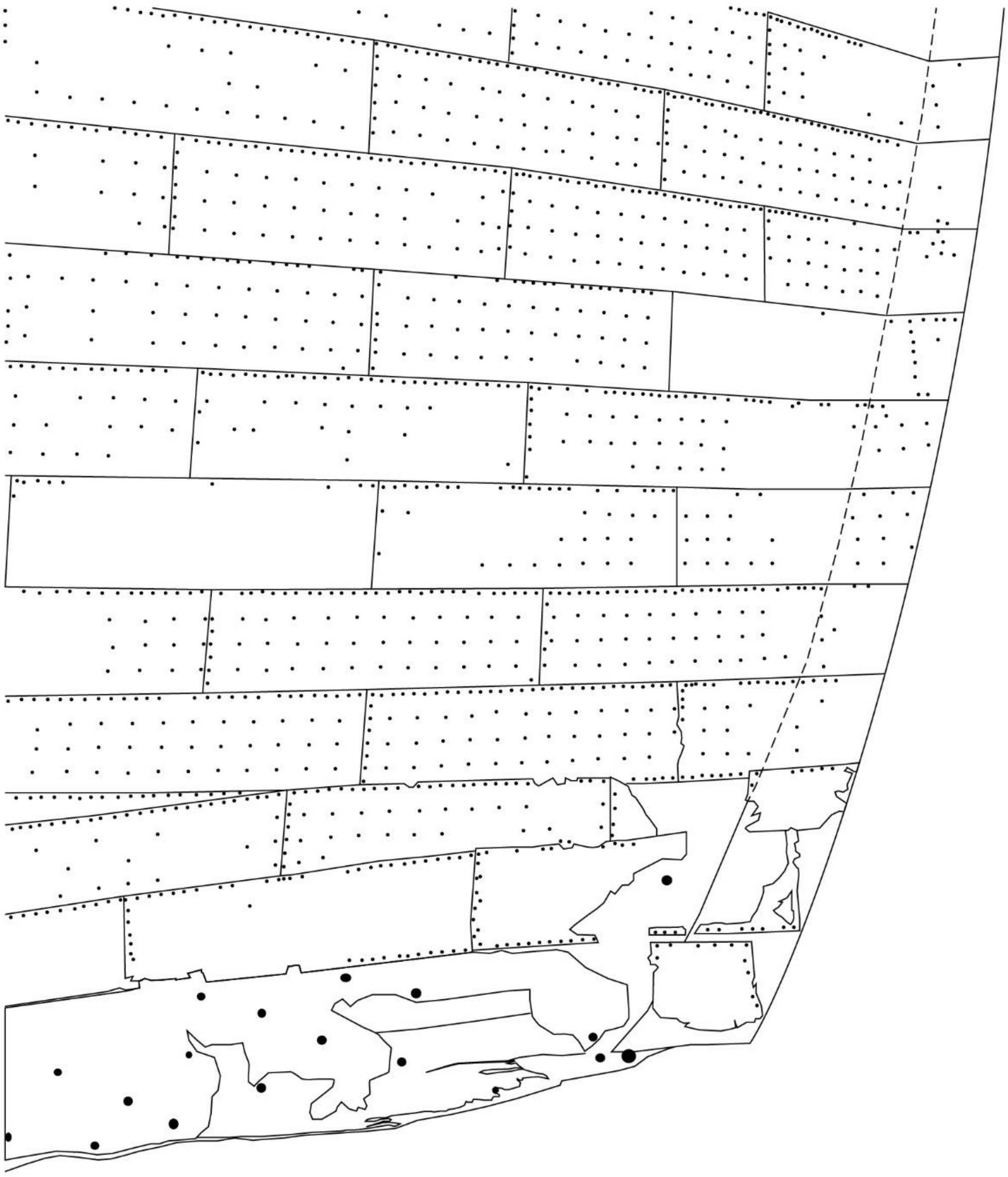

Figure 108. Arrangement of Muntz sheathing on the starboard bow of *Edwin Fox*. Note: where the tacks are not depicted is because of surface corrosion. Not to scale.

The sheathing tack shanks measured between 2 mm^2 at the tip and 4.5 mm in diameter below the head. The length of the shanks varied between 35 mm and 45 mm and the heads measured c.12 mm in diameter. The tacks examined showed the head was applied separately after the moulding of the shank.

A metal patent stamp on the starboard side of the hull identified the manufacturer of the sheathing. The patent stamp is located aft of midships on a piece of sheathing measuring 369 mm by 354 mm. The sheathing stamp was circular and read 45/MUNTZ’S PATENT/45 and 18 in the centre of the stamp (Figure 109). It is probable that this sheet of sheathing was cut down from a larger size. Other areas on the hull were searched for patent stamps, however, the established corrosion layer made it difficult to identify additional stamps. It was decided not to disturb the corrosion layer as it would increase the rate of further degradation to the metal. Therefore, only one stamp was located.

Figure 109. Muntz stamp recorded on the *Edwin Fox* hull.

7.4 Hull markings

Inscriptions were observed on the inside of *Edwin Fox*'s hull and were recorded during fieldwork between 22 to 25 April 2017. The inscriptions are located on the main mast step, rider keelson and on the forward stanchions (Figure 110). Additional markings were said to have been seen on the ceiling planking, starboard side, near the forward mast step when the hull was cleaned during the early 1990s (John Sullivan pers. comm. 2018). Upon inspection, however, no distinctive markings could be seen. It is possible they have been worn away as a result of foot traffic caused by public access to that part of the ship.

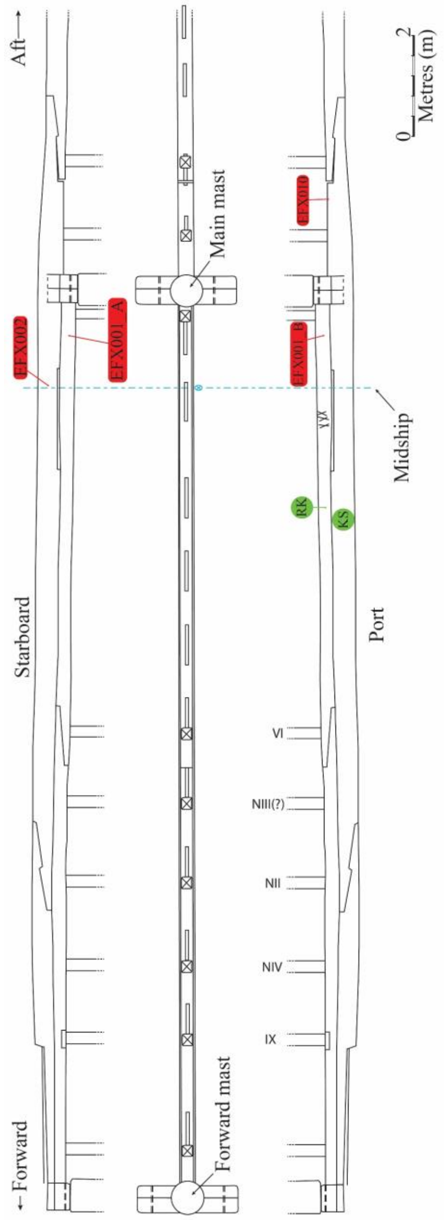

Figure 110. Site plan of markings in relation to *Edwin Fox*'s keelson, rider keelson, forward and main mast steps.

Only one inscription was observed on the main mast step. The marking can be read as a cursive ‘A’ with the cracked timber; however, it could also resemble a letter or number in a language other than English, or a symbol (Figure 111). The marking is located on the forward facing, port side of the main mast step and 265 mm from the top edge. It was thought that the inscription may have represented internal coding, so the forward mast step was checked for markings. It was not marked with any inscriptions, letters or numbers.

Figure 111. Carved letter, number or symbol on *Edwin Fox*’s main mast step.

The rider keelson also displayed markings on the port side between the forward and main mast step. Three X’s were inscribed into the timber, for example ‘XXX’. No other markings were observed around these or anywhere else on the rider keelson and adjacent keelson.

Between the main mast step and forward mast step, a total of six stanchions are lodged between the rider keelson and the main deck. Five stanchions contained different roman numerals. In order from the forward mast step to aft, the first stanchion did not have any markings, the second ‘IX’, the third ‘NIV’, the fourth ‘NII’, the fifth ‘NIII(?) and the sixth ‘VI’ (Figure 112). The markings were orientated 90 degrees, so they read vertically from top of the stanchion to the bottom of the stanchion. Other stanchions positioned on the rider keelson and keelson aft of the main mast showed no extant markings. The stanchions on the main deck were also checked for a numbering system, however, none displayed any inscriptions or markings.

Figure 112. ‘VI’ marking on the sixth stanchion, aft of the forward main mast.

7.5 Graving piece

A symmetrical shaped graving piece sits in one of the ceiling planks on the port side of the rider keelson. It measures 230 mm long by 95 mm wide at its widest point and resembles a convex irregular hexagon—coffin shaped (Figure 113). It is the only graving piece identified in the *Edwin Fox* hull to date.

Figure 113. Graving piece, portside, aft of forward mast.

7.6 Wood identification

The samples used for wood identification came from the cores drilled for dendrochronology, except for sample EFX011. This sample was extracted from an outer plank using a timber saw. Results from the wood identification are presented below (Table 25).

Table 25. *Edwin Fox* wood identification.

Sample #	**ID**	**Coring location**	**Scientific name**	**Common name**	**Function**
EFX001_A	RKS	Midship, starboard	*Cedrus deodara*	Himalayan cedar	Rider keelson
EFX001_B	RKS	Midship, port	*Cedrus deodara*	Himalayan cedar	Rider keelson
EFX002	KS	Midship, starboard	*Tectona grandis*	Teak	Keelson
EFX003	FL	Midship, centre	*Shorea robusta*	Sal	Floor timber
EFX004_A	M	Main mast, centre	*Cedrus deodara*	Himalayan cedar	Main mast
EFX004_B	M	Main mast, centre	*Cedrus deodara*	Himalayan cedar	Main mast
EFX005	CP13	Midship, port	*Tectona grandis*	Teak	Plank (#18)
EFX006	CS13	Midship, starboard	*Tectona grandis*	Teak	Plank (#18)
EFX007_A	K	Midship, port	*Tectona grandis*	Teak	Keel
EFX007_B	K	Midship, starboard	*Tectona grandis*	Teak	Keel
EFX008	TSS4	Midship, starboard	*Tectona grandis*	Teak	Plank (#14) (Thick strake)
EFX009	-	Midship, starboard	*Shorea robusta*	Sal	Frame (possible #2 futtock)
EFX010	KS	In between 5th and 6th floor timbers aft of midships, port	*Tectona grandis*	Teak	Keelson
EFX011	-	Stern, starboard	*Ulmus* spp.?	Elm	Outer most timber planking directly beneath metal sheathing

7.7 Dendrochronology

The author and Gretel Boswijk extracted 13 cores from timbers used in the midships construction of the *Edwin Fox* hull. The cored timbers included: the keel, the keelson, the rider keelson, a floor timber, ceiling planking, a frame and the main mast. The rudder was in too poor a condition for a solid core to be extracted. The coring of the mast provided an insignificant number of tree rings. Only EFX004A core was measured and counted 22 rings. EFX004B was not counted due to the lack of rings. The minimum number of tree-rings counted within these samples was 13 (EFX005) and the maximum was 169 (EFX007B). The ring count in the samples averaged 58.84. Five samples (EFX001A, EFX001B, EFX007A, EFX007B and EFX010) presented more than 50 rings and were deemed sufficient for cross-dating.

Dendrochronologists were contacted via the online International Dendrochronology Discussion Forum (ITRDBFOR) for chronologies specific to the tree species identified in *Edwin Fox*. Chronologies for *Tectona grandis* (teak), *Shorea robusta* (sal) and *Cedrus deodara* (Himalayan cedar) were requested through the online forum but only sequences for teak were available. This is due to chronologies still being refined and also due to the lack of date ranges fitting to the historical timeline of *Edwin Fox*. Three teak chronologies were made available and included Burmese teak, Thai teak and Java teak. Therefore, only the teak cores with more than 50 rings (EFX007A, EFX007B and EFX010) were cross dated (Figure 114).

The results for cross-dating with the master chronologies were inconclusive. The cores failed to provide a high value coefficient sufficient enough to determine a date range for the tree(s). Therefore, cross-dating neither showed felling dates or time periods for seasoning the timber. The parent tree used for the keel timber, however, was at least 169 years old. The results of the dendrochronological investigation are summarised in Table 26.

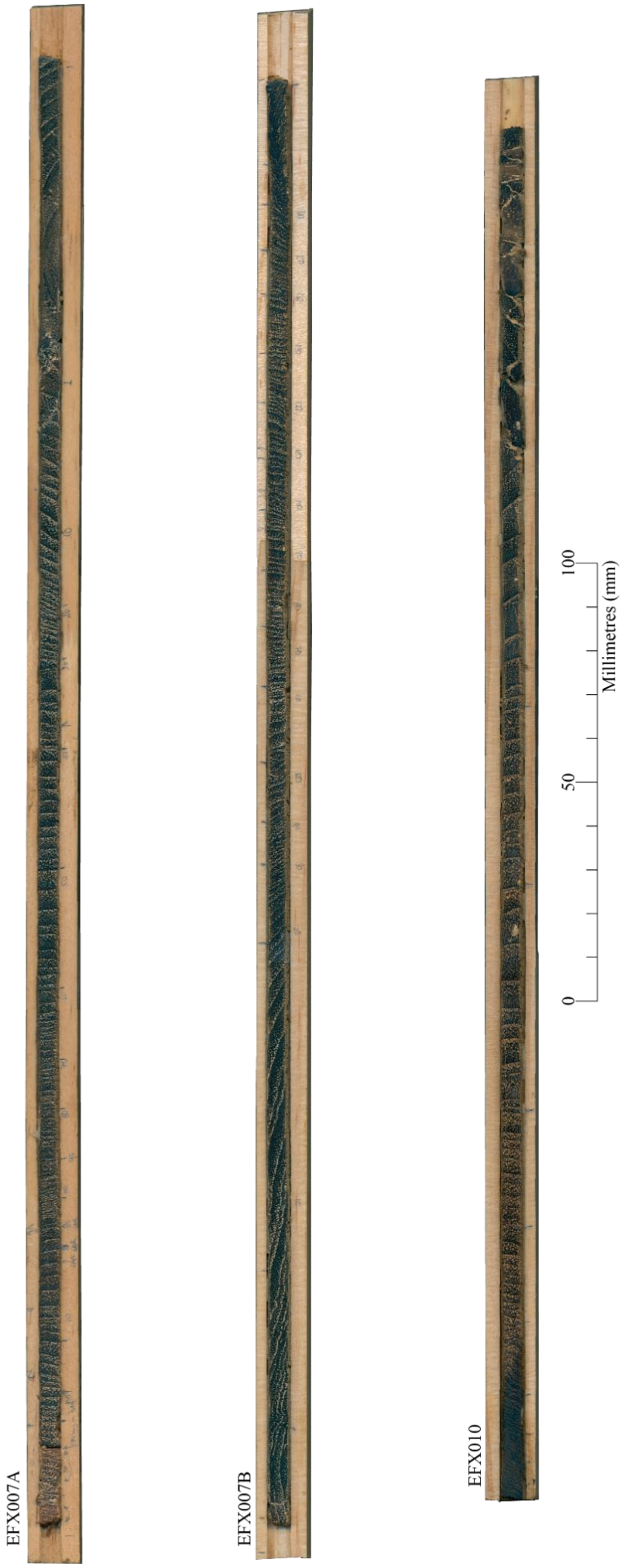

Figure 114. Dendrochronology core samples EFX007A (left), EFX007B (centre) extracted from *Edwin Fox*'s keel and EFX010 (right) extracted from the keelson.

Table 26. Details of dendrochronology cores collected from *Edwin Fox*.

EFX#	Timber	Hull location	Length x diameter (mm)	Scientific name	No. rings	Bark	AGR (mm)	Date span
001_A	Rider keelson	Midship, starboard side	148 x 10	*Cedrus deodara*	91	No	1.35	Undetermined
001_B	Rider keelson	Midship, port side	158 x 10	*Cedrus deodara*	62	No	1.70	Undetermined
002	Keelson	Midship, starboard side	111 x 12	*Tectona grandis*	35	No	2.97	Undetermined
003	Floor timber	Midship	143 x 8	*Shorea robusta*	43	No	-	Undetermined
004_A	Main mast	Main mast	75 x 8	*Cedrus deodara*	22	No	-	Undetermined
004_B	Main mast	Main mast	NA	*Cedrus deodara*	NA	No	-	Undetermined
005	Plank (#18)	Midship, port side	74 x 6	*Tectona grandis*	13	No	-	Undetermined
006	Plank (#18)	Midship, starboard side	87 x 8	*Tectona grandis*	33	No	2.33	Undetermined
007_A	Keel	Midship, port side	337 x 6	*Tectona grandis*	146	No	1.34	Undetermined
007_B	Keel	Midship, starboard side	332 x 6	*Tectona grandis*	169	No	1.14	Undetermined
008	Plank (#14)	Midship, starboard side	128 x 6	*Tectona grandis*	16	No	-	Undetermined
009	Frame (possible #2 futtock)	Midship, starboard side	112 x 6	*Shorea robusta*	41	No	-	Undetermined
010	Keelson	In between 5th and 6th floor timbers aft of midships, port side	314 x 6	*Tectona grandis*	94	No	2.35	Undetermined

7.8 Metal analysis

A total of nine samples including metal sheathing, a sheathing tack and a copper bolt used in the keel near the bow were collected for analysis. Only two sheathing samples were analysed as a representative sample of the sheets that covered the hull. A bolt and sheathing tack were also analysed. These materials were sampled to understand the differences in metal composition between the sheathing tacks and hull sheathing and to provide a comparison to the other three case studies. The collected samples are summarised in Table 27 and the results from analyses presented in Tables 28–30.

Table 27. A summary of the samples collected from the *Edwin Fox* hull sheathing.

Museum sample number	**Analysis sample number**	**Description**
EFX_CS1	CS001	*Edwin Fox* hull sheathing, portside bow.
EFX_CS2	CS002	*Edwin Fox* hull sheathing, portside midships.
EFX_CS-008	CS008	*Edwin Fox* bolt used in keel at bow.
EFX_CS-009	CS009.1	*Edwin Fox* rudder sheathing tack, starboard.
EFX_CS-009	CS009.2	*Edwin Fox* rudder sheathing tack, starboard.

Table 28. *Edwin Fox* hull sheathing elemental composition results.

	Wt%					**Atomic %**			
Description	**Cu**	**Zn**	**Pb**	**Total**		**Cu**	**Zn**	**Pb**	**Total**
CS001: spectrum 1	64.25	35.56	0.19	100		64.98	34.96	0.06	100
CS001: spectrum 2	63.52	35.10	1.38	100		64.78	34.79	0.43	100
CS001: spectrum 3	64.25	35.75	-	100		64.90	35.10	-	100
CS002: spectrum 1	64.23	34.93	0.85	100		65.25	34.49	0.26	100
CS002: spectrum 2	66.22	33.63	0.16	100		66.91	33.04	0.05	100
CS002: spectrum 3	65.53	34.47	-	100		66.11	33.81	-	100

Table 29. *Edwin Fox* elemental composition of white spots in the Muntz metal sheathing.

	Wt%					**Atomic %**			
Description	**Cu**	**Zn**	**Pb**	**Total**		**Cu**	**Zn**	**Pb**	**Total**
CS002: spectrum 4	5.46	4.02	90.52	100		14.69	10.53	74.77	100

Table 30. *Edwin Fox* elemental composition of the sheathing tacks.

	Wt%					**Atomic %**			
Description	**Cu**	**Zn**	**Sn**	**Total**		**Cu**	**Zn**	**Sn**	**Total**
CS009.1: spectrum 1	72.63	25.77	1.59	100		73.72	25.43	0.86	100
CS009.2: spectrum 1	74.36	23.89	1.77	100		75.47	23.56	0.95	100

Additionally, a non-ferrous bolt fixed into the keel near the bow was sampled. The bolt protruded horizontally into the keel and is likely to be a bolt for fixing the outer planking layer. The bolt was sampled by drilling into the head and collecting the shavings extracted by the metal. These were then mounted to be analysed (Figure 115). Drilling into the centre of the bolt reduced the possibility of contamination by corrosion products, which helped produce reliable results (Figure 116). The results of the metal composition are summarised in Table 31.

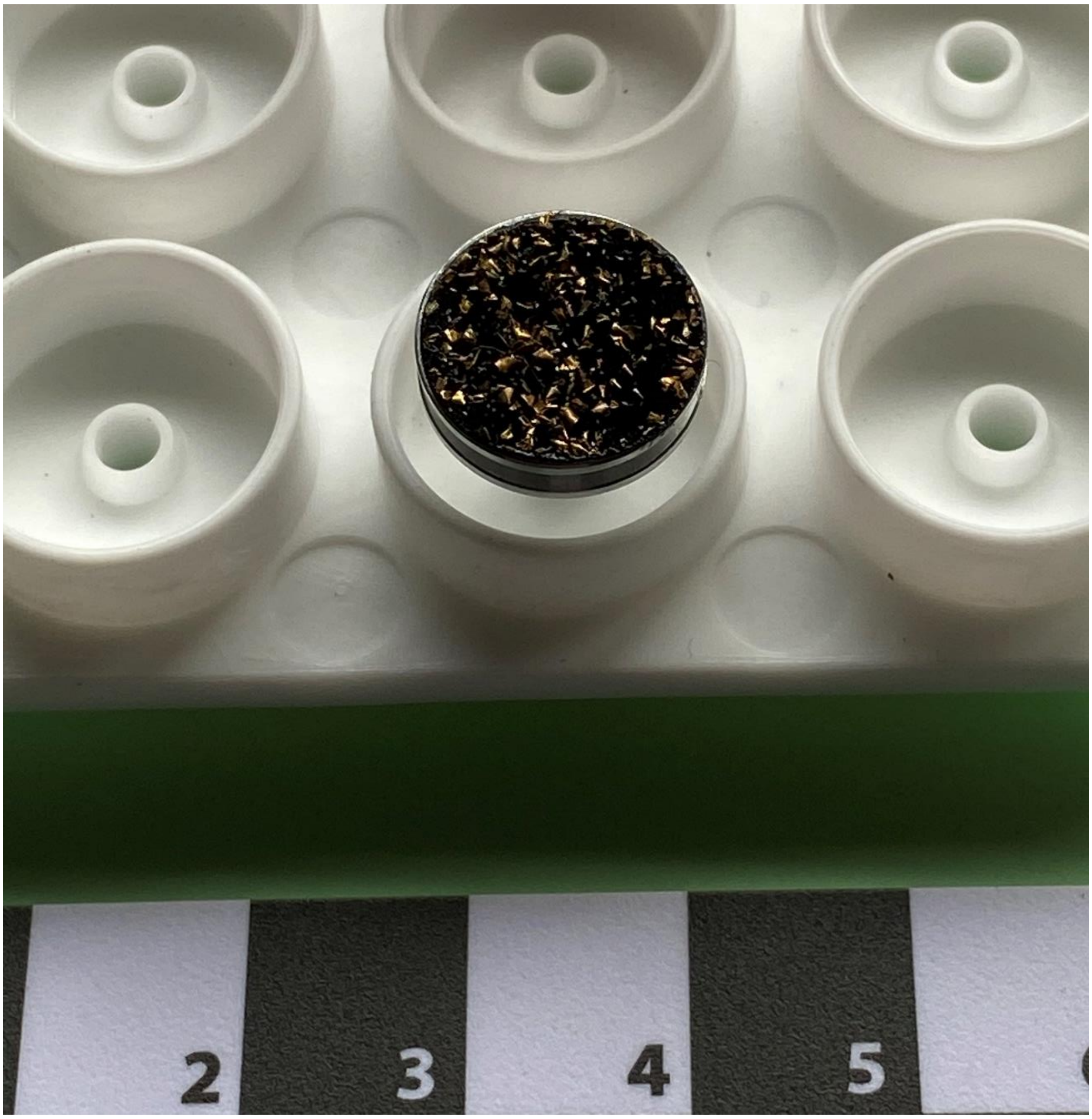

Figure 115. CS-008 set in resin before polishing (Photograph: Wendy van Duivenvoorde, 2020).

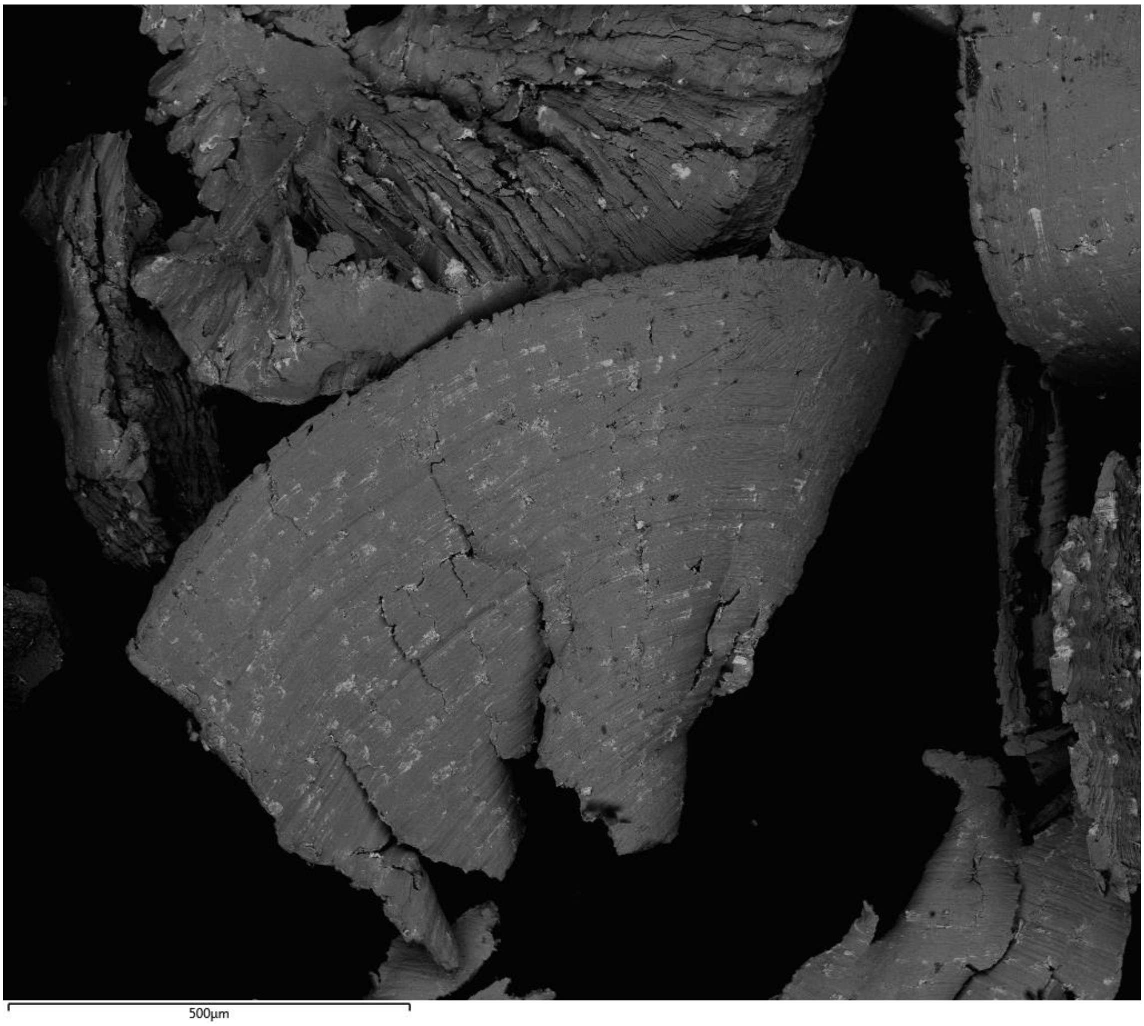

Figure 116. CS-008 shavings under microscope (Photograph: Wendy van Duivenvoorde, 2020).

Table 31. *Edwin Fox* elemental composition of bolt.

	Wt%						Atomic %				
Description	**Cu**	**Zn**	**Sn**	**Pb**	**Total**		**Cu**	**Zn**	**Sn**	**Pb**	**Total**
CS008: spectrum 1	76.80	13.40	2.39	7.42	100		73.93	25.50	0.87	0.20	100
CS008: spectrum 2	79.09	13.47	2.97	4.47	100		83.12	13.76	1.67	1.44	100
CS008: spectrum 3	77.08	13.21	3.55	6.16	100		82.26	13.70	2.02	2.01	100

The sheathing of *Edwin Fox* is consistent with that of ‘Muntz’ metal compositions. The sheathing recorded a composition of 33.63–35.75% zinc and 63.52–66.22% copper with little to no lead inclusions. The tacks that fastened the sheathing were manufactured using 76.80–79.09% copper, 13.21–13.40% zinc, 2.39–3.55% tin and 4.47–7.42% lead. The concentration of copper registered greater than the sheathing while including zinc and lead. The bolt made using an alloy consisted of c.72.63–74.36% copper, 23.89–25.77% zinc and some tin varying from 1.59–1.77 per cent.

7.9 Fibre identification

Two fibre samples were collected from the *Edwin Fox* hull that were directly attached to the ship's timbers. Hair sample HS-001, was collected near the bow on the starboard side and is a fibre matting placed between the two layers of outer hull planks. This fibre had no identifiable weave and the packing of the fibres appeared random in placement. Hair sample HS-002 was collected near the stern on the starboard side between two abutting horizontal edges of the most outer layer of hull planking. This fibre's function served as caulking creating a watertight seal between two planks. The results of the fibre identification are presented below in Table 32.

Table 32. Fibre samples from *Edwin Fox*.

Sample #	Function	Fibre	Notes
HS-001	Compressed matting between planks.	Goat hair	Poorly preserved and had a lot of dirt attached to them.
HS-002	Caulking in outer plank seams.	Hemp	Well preserved.

A third fibre sample consisting of different fibres was collected from the organic compound between the metal sheathing and the second hull planking layer. Different fibres exist within the pitch-like compound. Therefore, three visually different fibres were collected for analysis in order to understand the types of fibres included in the organic layer applied between the metal sheathing and outer planking. These results are summarised in Table 33.

Table 33. Fibres identified in the organic compound layer between the metal sheathing and outer planking layer on *Edwin Fox*.

Sample #	Function	Fibre	Notes
EF-003-A	Fibre mixed with organic compound between metal sheathing and outer planking.	Jute	Bast natural fibres.
EF-003-B	Fibre mixed with organic compound between metal sheathing and outer planking.	Twig?	Tiny fragment of wood with rootlets.
EF-003-C	Fibre mixed with organic compound between metal sheathing and outer planking.	Jute	Processed bast fibres. Twisted fibres, probable offcuts from rope.

Identification conducted by Henk van Haaster of BIAX Consults in the Netherlands revealed that there was no animal hair evident in the organic compound layer (Sample EF-003). The fibres are all plant based. EF-003-C was of notable difference with the appearance of twisted fibres, such as rope. Combined, these fibres are mixed with a resinous compound. Analysis and results of the resinous substance are presented in the next section.

7.10 Organic analysis

Sample EF_001_O1 was the only one collected for organic analysis. It came from the resinous layer located between the metal sheathing and exterior layer of outer hull planking. An area on the starboard side of the bow was identified as the best place for sampling due to accessibility and minimal corrosion product. The pitch-like compound is mixed with several different fibres which have been identified in the previous section. The second layer of goat hair matting between the first and second layer of timber planks did not contain any resinous substance. No sacrificial planking exists on *Edwin Fox*. Therefore, a representative sample was collected and analysed to understand the type of resinous substance used on the vessel. The results from the analysis are presented in Table 34.

Table 34. Pitch results from the *Edwin Fox* hull.

Sample	**Compound**	**Retention time (minutes)**
EF_001_O1	3-aminodihydro-2(3H)fluoranthene, TBDMS	14.3
	Hydroxylamine, 2 TBDMS	14.5
	Methoxy phenyl oxime	14.7
	TMS derived arsenous acid	15.8
	Azulene	19.1
	TMS derived p-coumaric acid	19.6
	Methenamine	19.7
	Diphenylacetylene	26.9
	5,8,11-heptadecatriynoic acid, methyl ester	28.8
	Benzene,1,1-(1,3-butadiyne-1,4-diyl)bis	29.8
	Retene	31.5

The resinous substance from *Edwin Fox* returned results with a mix of long chain fatty acids and elements consistent with hydrocarbons. The sample also contained fibres, which is different to the other samples collected from *Endeavour* and HMS *Buffalo*.

7.11 Summary

The historically preserved hull of *Edwin Fox* offered an opportunity to record ship's timbers with contextual data. This allowed for the positive identification of the timbers and their functions. The hull is constructed using teak, sal and elm timbers. The hull was sheathed using Muntz metal sheets with an added layer of fibre and pitch. The individual cataloguing of the timbers is now used to examine similarities and difference to the materials recorded for *Endeavour* and HMS *Buffalo*. Furthermore, the *Edwin Fox* timbers reveal design and construction elements necessary for answering the research question. Wood identification, metal, fibre and organic analysis contribute to understanding the technologies employed in building a vessel during the mid-nineteenth century.

Chapter 8. Discussion

This chapter combines historical research, archaeological data, wood identification and material analyses. In addition, the *Edwin Fox* dendrochronology data is incorporated to understand trees as a resource. Together, the similarities and differences in the data are discussed to shed light on changes in ship design and construction technologies related to British colonial ship constructed during the eighteenth and nineteenth centuries.

The chapter begins with briefly highlighting ships' hulls as a scientific resource to help understand past form, function and development of British merchant ships. Working with disarticulated hull timbers makes more difficult the task of determining the provenance of museum ship collections and is discussed here using the *Endeavour* and HMS *Buffalo* case studies. This is followed by reviewing the ship timbers recorded for this study, which includes both disarticulated ship timbers and the preserved historic hull remains of *Edwin Fox*.

Discussion of the three case studies is provided below with commentary assessment of changes in hull design and the similarities and differences between construction technologies. Combined, this analysis contributes to understanding the transfer of knowledge and technology within the shipbuilding industry. The processes of inventiveness, adoption and design are then explored. Finally, this chapter combines these previous discussions and explores shipwright behaviours toward constructing British colonial merchant vessels.

8.1 Ships' hulls as a resource

Through the works of Muckelroy (1978) and Gould (1983), ship studies developed a theoretical foundation through which to analyse and interpret shipwrecks. Their studies focussed on shipwreck site formation and vessels' social histories. Later, Steffy (1994) solely focussed on the shipwreck as a structure to understand its development, materials and function. This study builds upon these foundations by combining historical research, archaeological recording, wood identification, dendrochronology, material analysis and hull calculations to understand ship development. The methodologies employed in this research have subjected the archaeological and historical remains of the vessels to a scientific nautical archaeological investigation. Then by exploring these results through a behavioural framework, we begin to understand British shipwright behaviours towards constructing global watercraft during the eighteenth and nineteenth centuries. Furthermore, this work builds upon existing knowledge while recognising the artistry employed behind constructing some of the most complex human-made machines.

8.1.1 Disarticulated hull timbers

The *Endeavour* and HMS *Buffalo* museum collections consist of disarticulated hull timbers. Due to the national significance of the vessels and their public interest, over time, their wooden timber hull remains are dispersed throughout Aotearoa New Zealand. In total, three museum collections were visited to collect data and to combine into one data set. This served two purposes. The first was to assess similarities and differences in the timbers to determine if the disarticulated timbers are indeed from the *Endeavour* and HMS *Buffalo* ships, thus confirming the collection for the museums' records and to validate materials that are included in this study. The second purpose was to collate a comprehensive database of the material from these vessels. The *Endeavour* timbers, for example, displayed several diagnostic construction features comparable with the other case studies. In addition, the timbers provide new archaeological insights into the design and construction of a late-eighteenth-century British East Indiaman.

8.1.1.1 Determining provenance

The inclusion of museum disarticulated ship timber collections for this study was treated with caution because limited to no contextual information exists for the timbers. The museum materials were accumulated over several decades with various levels of provenance information. This meant the author assessed every timber based on museum records and diagnostic ship-related features.

The *Endeavour* timber collections recorded for this study were spread across two museums. Fortunately, materials labelled *Endeavour* were consistent with the recorded materials and dimensions at both museums. The Southland Museum and Art Gallery Niho o te Taniwha presented the largest collection of ship timbers and it was clear they originated from the same vessel and reflected their original catalogue entries. Each timber, however, was assessed for diagnostic features that would further confirm or deny the provenance of the material. For example, the application of sacrificial planks, copper fasteners and treenails all suggested a ship constructed at least towards the end of the eighteenth century. Wood identification further confirmed the timbers were probably European in origin. Additionally, there were fasteners in the collection that were discounted from the recording as they were identified as being manufactured in the late-nineteenth to the early-twentieth centuries. Furthermore, the historical record points to that material being from the *Endeavour* ship as it is the only known recorded timber ship that was either abandoned or shipwrecked in Facile Harbour, Tamatea Dusky Sound. The next closest shipwreck in the area is the iron-hulled SS *Waikare*, which sank in West Jacket Arm, Tamatea Dusky Sound, in 1910 (Ingram 1977:311–312). Therefore, the timber hull components in the museum collections are highly probable to have come from the *Endeavour* wreck site in Facile Harbour.

The HMS *Buffalo* collection at the Mercury Bay Museum was scrutinised because the materials do not reflect one period of salvage or acquisition. From the records, the timbers and artefacts on display were gifted to the museum as they were collected over time. Like *Endeavour*, the HMS *Buffalo* timbers and metal sheathing were assessed based on the original catalogue entry and diagnostic features. Wood identification confirmed the likelihood of the timbers belonging to a ship like HMS *Buffalo*. The metal sheathing was inspected for patent stamps. Four out of 11 fragments displayed marks, and one showed a Muntz metal stamp. This is discarded from the discussion because it is improbable that the hull was sheathed in Muntz metal at that date. Instead, the development of metal sheathing as an antifouling technology is discussed in the antifouling technology section of this chapter. Furthermore, the material collected on Buffalo Beach is most probably from the HMS *Buffalo* wreck because it is the only known shipwreck in the vicinity. Moreover, it is the only large ship to display early-nineteenth-century diagnostic features in the local area. For example, teak timbers, timber sheathing planks and copper sheathing. It is, therefore, more than probable that the timbers and metal sheathing included in this study are from the HMS *Buffalo* shipwreck.

8.1.2 Contextually preserved hulls

Edwin Fox is the last remaining preserved hull available for the study of British colonial-built merchant ships of the mid-nineteenth century. The ship's history is well documented as is the acquisition of the hull for museum display. The benefit of studying a preserved hull like *Edwin Fox* is that it provides contextual information for individual ship timbers. The disadvantage, however, is that a comprehensive investigation is limited because the ship cannot be broken down into individual components for study. Specifically, the inclusion of *Edwin Fox* in this study provides insights into how these ships were constructed and into the design parameters of hull shape.

8.2 The transmission of shipbuilding

This section explores the transfer of shipbuilding knowledge and technology using a combination of historical research and ship timber recording. Using the results from *Endeavour*, HMS *Buffalo* and *Edwin Fox*, this section discusses hull shapes and trees as a shipbuilding resource, and explores how timbers have been shaped and used in a vessel's construction. Similarities and differences between the three vessels are then highlighted and discussed.

Up until the 1780s, shipbuilding in India mostly employed local techniques and knowledge. The introduction of copper sheathing, however, is the first real introduction of technology that creates a hybrid style of vessel (Bulley 2000:27). Modification and refining methods contributed to the overall design of the hull that reflected the external façade of European ships. To achieve that result, however, local techniques were retained. Indian shipwrights were noted for excellent shipbuilding but their naval architecture was observed through a European perspective as 'being clumsy, unfinished, inartistic' (Bulley 2000:27). This is in contrast to eventual praising of the longevity of the Indian built ships, the solidness of their construction and the superior quality of teak versus oak.

Bombay ships were considered to be built strong and resilient (Bulley 2000:29). Specifically, Bombay-built ships were considered superior ‘merchantmen’ compared to their European equivalent and India-built ships using teak had long sailing careers. For example, *Milford*, a country ship built in Bombay in 1786 continued to be registered until 1829. After inspection for repair in 1810, the ship was assessed to be in good condition (Bulley 2000:29). This is compared to British-built ships, which the Company specified would sail for a maximum 12 years.

It is during this time that we observe the cross-cultural transmission of ideas, skills and technologies. The British and Indian shipbuilding industries were entangled through their global connections. At first, the British seemed reluctant to accept any other watercraft other than British built. Then an acceptance of foreign resources and shipbuilding techniques followed. In the following sections this flow of ideas, resources, design and technologies between foreign and domestic shipbuilding industries is considered.

8.2.1 Hull shape and structural concept

The idea of humans looking toward nature for design and construction inspiration is not a new phenomenon (see Khan 2017). Early developments in shipbuilding relied upon looking at natural creatures and their hydrodynamic forms when in the water. Mathew Baker’s widely used image of a fish superimposed on a sixteenth-century galleon (Adams 2013:115) demonstrates the original historical philosophy behind a ship having hydrodynamic properties while sailing. Ship lines plans from *Endeavour*, HMS *Buffalo* and *Edwin Fox*, highlight the differences and similarities in hull shapes. It is worth noting that directly comparing individual ship components is only one method for determining subtle differences in hull form and design. More generally, nautical architecture calculations demonstrate how the three primary case studies’ hull shapes altered over time. By understanding the overall design of the ship, a more comprehensive analysis can take place. Combined with archaeological data, we can assess knowledge transfer, adaptation and invention of materials and technologies as ship shapes are accepted through time.

The quantitative analysis of hull shapes is presented in Table 35. This data was calculated using the three formulas: the block coefficient, the prismatic coefficient and the midship coefficient. These coefficients illustrate how close the hulls are to a rectangular block and thus we can understand the changes in their shape over time.

Table 35. Summarised coefficient results for the three case studies.

	Endeavour	**HMS *Buffalo***	***Edwin Fox***
Block coefficient	0.6258	0.7014	0.5847
Prismatic coefficient	0.7381	0.7542	0.7018
Midship coefficient	0.8478	0.9299	0.8332

The block coefficient illustrates the most change between the vessels over time. Between *Endeavour* and *Buffalo,* the latter is mathematically more rectangular in shape. This squareness is clearly reflected in the lines drawings of the two vessels and shows *Buffalo* having a squarer bow compared to *Endeavour* (Figures 45 and 86). *Edwin Fox* on the other hand, is finer in shape when compared with the other two ships. This 'less-fulness' is seen through the refinement of hull shape with *Edwin Fox*. In particular, the shape of the bow is a noticeable design change. The bow has an increased rake and is no longer 'bluff' in shape like the other two vessels. This design change produces a finer hull shape in the water.

The prismatic coefficient reveals all three ships are similar in displacement design. This demonstrates that the ratio of displacement over time has remained relatively standard. Therefore, the vessels displaced similar volumes in relation to one another. This consistent shape of displacement likely reflects the cargo carrying function of the vessel, whereby capacity was prioritised over speed. Furthermore, the consistent displacement through time maybe a reflection of the ships needing to access shallow ports located up rivers, such as Calcutta.

The midship coefficient indicates the three vessels have relatively similar volumes in relation to the outer bounding box. Based on these coefficients, the midships areas are mostly square. HMS *Buffalo*, however, is highlighted as having the squarest midship area, whereas tumblehome design of *Endeavour* makes its sides less square in cross-section. In general, it is argued here that the midship area in British East Indiamen remained relatively consistent over time. Interestingly, this is irrespective of whether the vessel was constructed with tumblehome walls or straight sides.

To complement the coefficients, a simplified method used for analysing hull shapes includes calculating the length to breadth ratio (L:B). Eric McKee (1983:79 and 81) classified hull shapes based on their design ratio (Table 36). This classification presents a basic description of the vessel's shape longitudinally from bow to stern. After calculating the L:B ratio for the three ships, they are easily classified (Table 37).

Table 36. L:B ratio and vessel design classification (after Mckee 1983).

L:B ratio classification	
≤2.6	Beamy
2.7–3.74	Normal
≥3.75	Narrow

Table 37. *Endeavour*, HMS *Buffalo* and *Edwin Fox* hull shape classified.

Ship	**Ratio**	**Classification**
Endeavour	3.82	Narrow
HMS *Buffalo*	3.63	Normal
Edwin Fox	4.96	Narrow

Interestingly, McKee's (1983:79 and 81) L:B ratio classified *Endeavour* as narrow—it was hypothesised that *Endeavour* would be beamy as a result of its tumblehome design. Proportionately, the vessel's length to breadth dimensions are considered narrow in design. This addresses the previously reported 6:1 ratio of length to breadth as stated by Boocock and Kenderdine (1992:2) and redefines *Endeavour* as closer to having a 4:1 length to breadth ratio. Therefore, hull shapes remained consistent over time with the exception of HMS *Buffalo* being constructed more bluff in shape. This difference coincides with the shift to allowing British ships to be built in India experienced around the turn of the nineteenth century. Therefore, the boxier shape in *Buffalo* is a possible reflection of local shipbuilding practices adapting to required British hull design parameters.

Vessel tonnages provide another form of assessing ships sizes and are often reported in published materials after quoting historical texts. Ship's recorded tonnages in the late eighteenth century, however, appear to change for the same vessels over time. Except for a few, most of the Company's chartered ships were recorded as exactly 499 tons between 1748 and 1772 (Cotton 1949:40). For example, *Endeavour* for its first voyage was recorded at 499 tons in 1771. Then for the second, third and fourth voyages it registered 761 tons and the fifth voyage, 758 tons ([BL] ORB 30/889).

The overall hull dimensions, however, remained the same. The ship measured 42.31 metres (138 ft 9.75 in) long by 11.04 metres (36 ft 2.65 in) broad. It is possible after the vessel's refit in the mid-1780s, the dimensions were changed, but is unlikely to have affected the hull tonnage by a difference of approximately 250 tons.

The likely cause for discrepancies in its registered ships' tonnage is company policy. Evan Cotton (1949:40) noted the 'actual tonnage of an Indiaman by no means corresponded with the registered total.' The law at the time required ships registered over 499 tons to carry a chaplain. The reason for this was for the Company to save expense and to appear to 'keep within the letter of the law' (Chatterton 1912:183). Instead, ships of 499 tons only required to sail with a captain, four mates, a surgeon and a purser. *Endeavour*'s second voyage departing December 1774, however, shows the vessel's tonnage increased. This ship was probably remeasured using the new measurement for tonnage, labelled the 'Builder's Measure' and adopted by the British Parliament in 1773. Thus, *Endeavour*'s tonnage reflects changes in Company policy verses the refinement of maritime law at the time. Therefore, when considering historical records, comparing tonnages is not entirely accurate for determining changes in design.

8.2.1.1 Summary

In principle, the three ships examined here remained relatively rectangular in shape. It is, however, apparent that their design does become more box-like around the early nineteenth century with HMS *Buffalo* as the example. The same ship also retained eighteenth century hull design characteristics such as the bluff bow which is slightly more exaggerated than previous designs. A subtle difference, however, is the squarer form of the sides of the vessel—there is less of the tumblehome towards the sheer. These square sided adaptations are, mathematically, representative of the hull as being more rectangular in shape in cross-section across the beam.

The most visible changes in design are evident with *Edwin Fox*. Whilst the hull retains the refined vertical sides observed on HMS *Buffalo*, its bow is less bulbous. The stem has a greater rake and is sharpened to slice through the water rather than push like the bows of *Endeavour* and HMS *Buffalo*. The stern becomes squarer in shape and towards the mid-nineteenth century loses the extravagant decorated stern castle seen in earlier examples. This sleekness in design gives a clean run[14] along the hull, which is an extension from the then historic ship shapes. With this understanding of hull shape over time, we can now analyse the individual timber components and reveal how technologies, shipwright learned behaviours and external factors influenced ship manufacture.

8.2.2 Trees as a resource

Trees were critical for shipbuilding during the eighteenth to mid-nineteenth centuries. The exception being the introduction of iron hulls and their eventual adoption during the 1800s. The results from the timber sampling are combined here to discuss the use of different trees in ship assemblages. It was intended for the dendrochronology to provide insights into age, seasoning and pairing of trees used in *Edwin Fox*; however, after comparing the data against (current) master chronologies, the felling ages of the timbers could not be determined. Instead, other valuable insights are gleaned from the types of wood used in the vessels' construction. In addition, the hypothesis of the pairing of planks from the same parent tree used in *Edwin Fox* is discussed here. This section combines the archaeology with historical research to discuss the changing attitudes towards timber adoption in British colonial shipbuilding.

The wood species identified in the construction of *Endeavour*, HMS *Buffalo* and *Edwin Fox* reflects their geographic origin of construction. This is evident through the use of teak and sal for HMS *Buffalo* and *Edwin Fox* (Table 38), whereas *Endeavour* was mostly constructed with elm. Elm was considered an important tree for shipbuilding and in the seventeenth century and English ships frequently had long structural timbers fashioned from elm wood (Salisbury and Anderson 1958:6, 10). It was also useful for floor timbers, cross chocks, midships, lower futtocks and planking (Blackburn 1817:162). The archaeological record complements the historical record while at the same time providing evidence for where elm was installed in the ship. Compared to the historical record, the archaeology tells us that elm was also suitable for the keel—a significant component of the ship. Teak was observed for the outer hull components, including planking and sacrificial planking.

[14] Run describes a hull which does not create undue turbulence when it is easily propelled through the water (Costley 2014:40).

It is unknown when the teak was added, but this offers insights into how teak was used in British yards in the late eighteenth century. It is clear that *Endeavour* was constructed using British or European timbers with Asian timbers used for outer protective layers. This demonstrates that British shipwrights were beginning to understand how to work with teak towards the end of the eighteenth century. Furthermore, it could reflect attitudes of the owners and operators of the shipyards at the time, whereby they were not initially socially accepting of using foreign timbers in their ships—reserving foreign timber for the outer sacrificial layer.

Table 38. Wood used in *Endeavour,* HMS *Buffalo* and *Edwin Fox* (presented with both scientific and common names).

Feature	*Endeavour*	*HMS Buffalo*	*Edwin Fox*
Keel	*Ulmus* spp.? (elm)	Unknown	*Tectona grandis* (teak)
False keel	*Ulmus* spp.? (elm)	*Tectona grandis* (teak)	*Tectona grandis* (teak)
Keelson	Unknown	Unknown	*Tectona grandis* (teak)
Rider keelson	Unknown	Unknown	*Cedrus deodara* (cedar)
Floor timber	Unknown	Unknown	*Shorea robusta* (sal)
Futtock	*Quercus* spp.? (oak)	*Quercus* spp.? *(oak)*	*Shorea robusta* (sal)
Garboard strake	*Ulmus* spp.? (elm)	Unrecorded	Not sampled
Outer planking (first layer)	*Ulmus* spp.? (elm), *Tectona grandis* (teak)	*Tectona grandis* (teak)	*Tectona grandis* (teak)
Outer planking (second layer)	N/A	N/A	*Ulmus* (elm)
Sacrificial timber plank	*Tectona grandis* (teak)	*Cedrus* spp.? (cedar), *Pinus* spp.? (pine)	N/A
Ceiling planking	*Ulmus* spp.? (elm)	Unrecorded	*Tectona grandis* (teak)
Knee	Not sampled	*Shorea robusta* (sal)	Not sampled
Treenail	*Quercus* spp.? (oak)	Not sampled	Not sampled

Edwin Fox's main keel at midships was cored at a 45-degree angle from both the port and starboard sides. This ensured the core captured the most tree rings in cross-section through the sapwood and into the pith. Existing literature described how trees were not calculated from their growth of a single stem, but chosen for technical reasons and specific to the required ship component (Bulley 2000:96). In addition, if cut too young, teak was considered susceptible to dry-rot, which would have had potentially fatal consequences for the ship's structure (Blackburn 1817:154). While the keel's tree rings could not be cross dated, the number of rings indicated the tree was 169 years old when cut down. Therefore, it is probable that older trees were chosen on a technical basis and for larger components of the vessel.

Opposing ceiling planks in *Edwin Fox* were cored to test whether the timbers when laid in the same location on the port and starboard sides were from the same parent tree. This hypothesis was further supported by visual arrangement of the ceiling planks and the thick stuff (footwaleing and futtock planks) being mostly symmetrically laid with minor variation in their lengths. Thus, opposing ceiling planks CP13 and CS13 were cored to test this hypothesis. Normally, for non-modern assemblages, *t*-values greater than ten provide some indication of the timbers originating from the same tree (Heritage 2004:12). The core samples (EFX005 and EFX006), however, only recorded a short series which gave limited results. EFX005 counted 12 rings and EFX006 counted 32 rings—the minimum requirement being ≥50 rings. While the ring count is small, interestingly, the two cores can be overlapped with each other. This, however, occurs between two different ring ranges. First, the overlap is between year three and year 16. Second, the overlap can also fit between year 16 and year 28. The overlap suggests pairing from the same tree might have occurred, although the number of counted rings hindered the accurate assessment of pairing. The result of two possible areas of matching means the pairing of ceiling planking remains inconclusive.

Evidence of labour and wood working were recorded in all three case studies. Different tool and wood working marks were identified as adze, mechanical saw, chiselling and scoring. Inscriptions of numbers and letters were only visible in the *Edwin Fox* hull. These markings and techniques are interpreted as timber preparation because they relate to preparing timbers for their function within a ship's hull. The recorded types of tool and construction marks are summarised in Table 39.

Table 39. Evidence of tool marks recoded on *Endeavour*, HMS *Buffalo* and *Edwin Fox*.

Ship timber	*Endeavour*	*HMS Buffalo*	*Edwin Fox*
Keel	Adze, scoring	Unknown	None observed
False keel	None observed	None observed	None observed
Keelson	Unknown	Unknown	Possible adze
Rider keelson	Unknown	Unknown	Possible band saw
Floor timber	Unknown	Unknown	Possible adze
Futtock	None observed	None observed	None observed
Garboard strake	Saw marks	Unknown	None observed
Outer planking (first layer)	Adze, possible saw marks, straight saw marks, circular saw marks, angled cuts, chisel, scoring.	Unknown	None observed
Outer planking (second layer)	N/A	N/A	None observed
Sacrificial timber plank	None observed	Adze, saw marks	N/A
Ceiling planking	None observed	Unknown	Scoring and possible chisel
Knee	Unknown	None observed	No timber knees

Overall, shaping of timber components was not visible across comparable timbers within the three case studies. The evidence of mechanical sawing, however, provides insight into how the timbers were prepared. The *Endeavour* timbers displayed a mixture of straight and possible circular cuts. These are identified as being mechanical because the saw marks are uniformly spaced (5 mm–7 mm) (Figure 117).

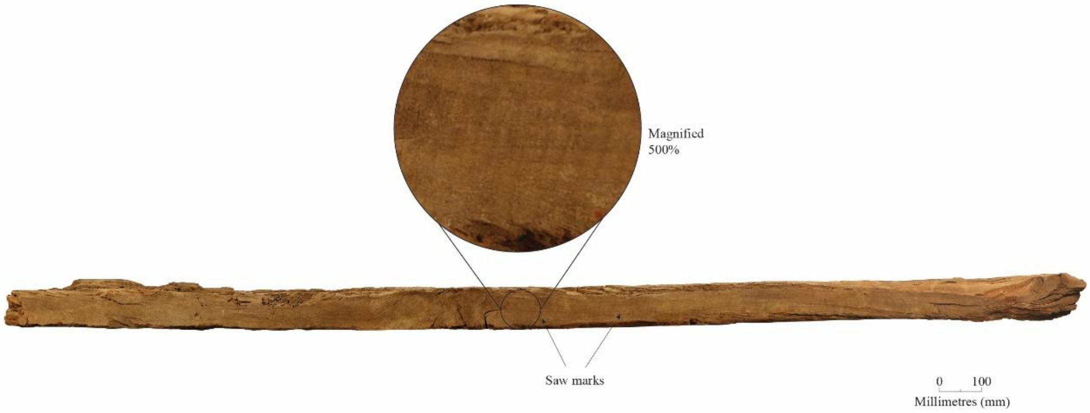

Figure 117. Possible circular saw marks recorded on END_021 with detailed magnified.

The identification of straight and circular saw marks on the timbers suggests different technologies were employed in preparing the timbers for the ship. *Endeavour* has evidence of definite straight and possible circular saw marks, which suggests two forms of milling technologies were available for serving shipbuilding timber requirements. There is conjecture as to when the circular saw was invented in

Britain but a patent was awarded to Stephen Miller in 1777 (Ball 1975:79–80). Therefore, the date of this patent postdates the original construction date of *Endeavour*. On one hand, the circular saw is likely to have been in use prior to the official patent date. On the other hand, the planks with circular saw marks may be linked to the repair and the rebuild of the vessel in the 1780s. Despite this, it is conclusive that straight sawing methods, with the possible introduction of circular saw blades, were used for milling timber suitable for constructing ships in the late eighteenth century.

Individual ship planks recorded adze working. The adze markings were observed mostly on the inner faces of the ceiling, outer and sacrificial planking. The shipwrights or labourers used the adze to shape the timber face and to work the timber flush. The timbers would be cut to ‘near-enough’ the required dimensions and further trimmed with adzing or chiselling (Bill Leonard pers. comm. 2020), thus shaping the timbers to follow the lines of the hull.

Markings such as numbers and letters were only recorded on *Edwin Fox*. These included ‘XXX’ on the rider keelson forward of the main mast, a possible letter ‘A’, number or symbol on the main mast step and roman numerals on the stanchions directly aft of the forward mast. It is hypothesised that the stanchion numbers assisted with their removal when loading and unloading cargo or for carrying out major repair (John Sullivan pers. comm. 2018). It is possible that similar inscriptions once existed on the other two case studies, however, due to degraded, weathered, or contemporarily modified surfaces, such markings remain unrecorded.

It is unknown what the rider keelson letters mean. If interpreted as roman numerals, it can be read as the number 30, however, this in no way reflects any of the timber’s measured dimensions (both metric and imperial) nor the inscription’s location on the timber. The letters were also inscribed after the timber had been milled for its function as a rider keelson. It is probable the ‘XXX’ is an internal coding system, although it is uncertain if this was employed during construction or when the vessel was in operation.

Another inscription was recorded in the hull of *Edwin Fox*. A marking inscribed into the forward port side of the main mast step that can be read as a symbol or number created by two different carvings, or when combined resembles a cursive ‘A’. The design of the carving was checked against common numbers and alphabets around India and none confirmed the meaning of the symbol. No other mast steps had similar or corresponding markings. Thus, interpreting this symbol is not possible at this time.

Archaeological evidence of graving pieces was observed and recorded on *Endeavour* and *Edwin Fox*. Both revealed unique shapes and placement of the pieces. The graving pieces observed in *Endeavour* and *Edwin Fox* are the result of shipwrights removing knots within the timbers for functional or aesthetic reasons. Additional insights gleaned from these construction features are the shipwright’s attention to detail and likely self-pride in their own work. The removal of a knot in a timber can also be considered as removing a structural weakness within the timber’s own natural structure, therefore maintaining potential structural integrity within the ship’s hull.

In summary, the analysis of the timber components recorded in the three case studies reveal how ships were constructed with different types of wood. While dating the *Edwin Fox* timbers was inconclusive, other insights contribute to our understanding about how trees were being used in these vessel’s construction. Furthermore, the identification of construction and tool marks reflect developing mechanised milling and the attention to detail directed by the artisan. Finally, timber selection reflects the increasing accessibility to foreign timber resources and addresses shipwrights’ abilities to adapt to new materials when working in the shipyards.

8.2.3 Assembling the hull

The hull timber components recorded for this study highlight diagnostic shipbuilding features and are used to discuss their differences and similarities over time. The hull timbers discussed are a representative sample of the three case studies recorded in museum collections. Together, they present nautical archaeological evidence towards the development of BEIC ship hulls.

8.2.3.1 Keel

The keel fragments from *Endeavour* and the preserved keel from *Edwin Fox* were available for recording, while the moulded dimension for HMS *Buffalo* was estimated from the false keel measurements. Both the *Endeavour* and *Edwin Fox* keel timbers presented maximum measurements for the moulded and sided faces (Table 40). The lengths were measured to their preserved extent with only *Edwin Fox* having a complete keel length from stem to stern post.

Table 40. Summarised recorded keel dimensions of *Endeavour*, *Buffalo* and *Edwin Fox*.

Ship	Max moulded (mm)	Max sided (mm)	Max measured length (m)	Historically recorded length (m)
Endeavour	369.5	366.5	NA	33.87
Buffalo	345*	Unknown	Unknown	30.10
Edwin Fox	345	440	42.48	NA
NB: *measurement repeated from the false keel.				

Endeavour's keel is fashioned from elm wood and was converted whole from the parent tree. The final shape resembling a square shape in cross-section. The evidence of a scarf joint suggests *Endeavour*'s keel was made up of several individual timber sections. The recorded timber section presented a vertical scarf joint meaning it was arranged with two timbers joined side by side and not top to bottom. Possible copper alloy keel bolts used along the keel indicate how the keel was fastened to the adjoining floor timbers and false keels.

No archaeological remains of HMS *Buffalo*'s keel were available for recording. To understand the possible size of the keel, the moulded dimension was transferred from the false keel timber. Due to the absence of archaeological material, the evidence of joints and fasteners is limited for comparative study.

The keel of *Edwin Fox* was intact from bow to stern and measured 42.48 m. The keel appears to be more rectangular in cross-section with the sided measurement greater than the moulded measurement. The entire length is constructed using four separate teak timbers. The section of keel that intersected the midship line has evidence of scarf joints at both ends. The scarf joints are orientated horizontally meaning the two adjoining timbers are placed one on top of the other instead of side by side. This is different to the scarf joint arrangement recorded on *Endeavour*. The types of fasteners used in the preserved keel were concealed in the timber assembly and inaccessible for recording.

When *Endeavour* and *Edwin Fox* are assessed together, the recorded dimensions suggest the keels' cross-sections were squarer during the eighteenth century. By the mid-nineteenth century the keel's cross-section becomes more rectangular in shape. The sided dimension, however, increases while the moulded dimension decreases over time. This suggests proportional measurements in relation to the overall size of the vessels. It is argued here that the dimensions used for the keels slightly increase with time and are probably a result of timber selection while reflecting the proportions of the ships' overall sizes.

8.2.3.2 False keel

A false keel attached to the underside of a ship's keel is used as protection from damage caused by unexpected impact with submerged debris or the seafloor. The false keel is designed to be easily removed, either from unintentional damage or for repair. All three primary case studies provided evidence to record the false keel as a ship component which reveals a type of technology used for protecting the ship's structure (Table 41).

Table 41. Recorded false keel dimensions.

Ship	Preserved moulded (mm)	Max. moulded (mm)	Max. sided (mm)	Max. length (mm)
Endeavour	305	NA	138	Unmeasured
Buffalo	NA	345	90	Unmeasured
Edwin Fox	NA	342	115	Unmeasured

Only *Endeavour* recorded a preserved moulded measurement, but it is likely to measure the same moulded dimension of the keel. This places *Endeavour*'s false keel at 369.5 mm. Therefore, when assessing all three false keels, their moulded measurement reflects the keel dimensions and reduces proportionately over time. The sided dimensions, however, appear to be irregular and do not follow a consistent trend over time. When considering the ships' overall keel lengths, the false keel sided measurements are probably proportional to this measurement.

The wood chosen for ships' false keels reflects their domestic and colonial timber resources. *Endeavour*'s false keel is fashioned from elm, whereas both *Buffalo*'s and

Edwin Fox's false keels are teak. None displayed how they were cut or shaped due to surface degradation or being covered in metal sheathing.

The false keel sections showed timber joints where each timber was connected to the next. Both HMS *Buffalo* and *Edwin Fox* recorded evidence of timber joints. A type of box joint shows that similar wood working joints were used in the formation of the false keel to protect the main keel from bow to stern. The box joint is a simple link that is easily crafted and therefore provided easy fitting for the individual false keel pieces (Figure 118).

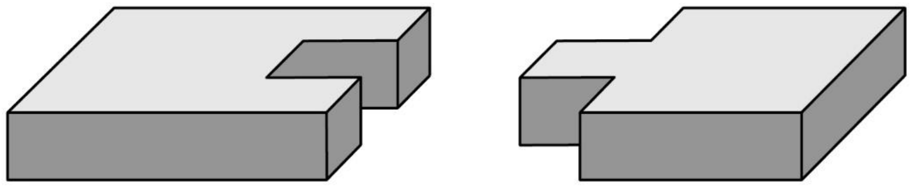

Figure 118. Box joint schematic.

8.2.3.3 Keelson

The keelson is a longitudinal timber orientated bow to stern and placed above the keel. This timber is usually positioned atop the floor timbers, increasing the longitudinal strength of the vessel. *Edwin Fox* was the only ship to present a keelson for recording. The keelson is similar in dimensions to the main keel. At midships it measured 470 mm moulded by 350 mm sided. The keelson is scarfed in three places and is placed between the forward mast and the inner stern post. The section of timber that intersects midships measured 21.67 m long. The fasteners used for fixing to the floor timbers could not be determined without disassembly.

Edwin Fox's keelson presents new insights that add to our understanding of the vessel's construction. The size of the timber suggests the importance of this timber's role to strengthen the ship longitudinally. Gould (2000:73) has argued that during the nineteenth century, wooden ships were becoming larger and needed reinforcement for hull strength, especially against stresses such as hogging and sagging. The keelson in *Edwin Fox* is a substantial piece of teak, and the shipwright would ensure its intended function supported the overall size of the ship. Longitudinal structural integrity is further supported by the addition of the rider keelson, which is positioned between the main mast and forward mast steps. This additional length of timber ensured the ship remained strengthened in the bilges.

8.2.3.4 Bilge keelson

In addition to *Edwin Fox*'s central keelson, the hull is reinforced with two parallel bilge keelsons. These are positioned longitudinally (bow to stern) between ceiling planks four and five on both the port and starboard sides and serve dual functionality. The first purpose is providing additional longitudinal structural support for the hull, and the second is providing mortise and tenon anchoring points for timber stanchions supporting the deck beams above. The bilge keelsons are placed relatively symmetrically in the hull. Although, there are no other bilge keelsons to compare across the three other case studies, it shows hulls in the mid-nineteenth century were being constructed with longitudinal and vertical strengthening in mind. Furthermore, the lengths between scarf joints suggest large straight trees were being targeted for these structural beams rather than being made of several smaller components. The scarf joints also demonstrate the importance of having strong timber joins that support integral components of the hull.

8.2.3.5 Futtocks

All three primary case studies have evidence of futtocks and were available for recording. Maximum dimensions were measured where possible, however, the maximum lengths across the three vessels could not be measured. This was because the ends were either broken or degraded and *Edwin Fox*'s individual futtock ends were not accessible. The Southland Museum and Art Gallery Niho o te Taniwha's *Endeavour* timber collection contained two futtock fragments for recording. Only one fragment recorded a maximum moulded measurement of 192 mm (END_013), however, the other fragment (END_007) recorded a preserved measurement of 295 mm. The sided measurements were preserved and measured between 132 mm (END_013) and 199 mm (END_007). HMS *Buffalo* had one futtock timber fragment for recording and *Edwin Fox* with its preserved hull presented moulded and sided dimensions. Due to variations with the maximum measurements across each hull's fragments, the dimensions have been averaged in Table 42.

Table 42. Futtock dimensions measured on *Endeavour*, HMS *Buffalo* and *Edwin Fox*.

Ship	**Preserved moulded average (mm)**	**Max moulded average (mm)**	**Preserved sided average (mm)**	**Max sided average (mm)**	**Maximum length (mm)**	**Joints**
Endeavour	293.5	192	165.5		Unknown	Undiagnostic, possible scarf joint.
Buffalo		212		155	Unknown	Possible scarf joint.
Edwin Fox		280		170–570	Unknown	Possible butt and chock.

The degraded futtock fragments of *Endeavour* and HMS *Buffalo* recorded various preserved dimensions. The inclusion of preserved measurements here indicates an approximate dimension for the futtocks used in the vessels' construction. *Endeavour* showed an inconsistency between its preserved and maximum moulded measurements, with the preserved measurement being larger than the latter. The identified futtocks are probably from different components that make up a complete frame. Thus, the larger preserved measurement is possibly a futtock that was located between the turn of the bilge to adjoining floor timbers. The other futtock fragments were probably used higher up in the frames toward the gunwales.

The maximum average moulded and sided dimensions for the three case studies are relatively similar. Over time, the moulded dimension increases while the sided dimension decreases by 10 mm with the construction of HMS *Buffalo* and then increases >20 mm in *Edwin Fox*. This slight decrease in futtock sizing during the construction of HMS *Buffalo* is likely to be a factor which is proportionate to the vessel's overall size—*Buffalo* is smaller in both length and breadth compared to the other case studies. Furthermore, *Edwin Fox* had sided dimensions up to 570 mm. This is because the futtock needed to be the same sided dimensions as other floor timbers to ensure the ceiling planking was laid flat and to maintain structural integrity with adjoining ship timbers. In conclusion, futtocks across approximately 80 years of shipbuilding and two different geographic locations remained relatively standard. Their moulded dimensions increased and the sided measurements only varied proportionately to the size of the vessels.

8.2.3.6 Garboard Strake

Endeavour and *Edwin Fox* presented garboard strakes for recording. The total length of the strakes could not be measured because the ends were either covered by metal sheathing or broken. The *Endeavour* garboard strake measured 291 mm wide and 141 mm thick. *Edwin Fox*'s garboard strake measured 380 mm wide and between 62 mm and 65 mm thick for both the port and starboard sides. The garboard strake of *Edwin Fox* is therefore wider by 98 mm, whereas *Endeavour*'s garboard strake is thicker by 76 mm. The wood used for the two ships is also different. *Endeavour*'s strake was shaped from elm and while *Edwin Fox* was not sampled, it is probably made of teak (Lloyd's Register Foundation [LRF], Survey Report for *Edwin Fox*, 21st June 1854, LRF-PUN-LON634-0500-R). It is possible, the choice of teak may have influenced the dimensions required for the garboard strake and reflects the change in thinness over time.

8.2.3.7 Outer hull planking

Endeavour and *Edwin Fox* both had outer hull planking available for recording whereas no outer hull planks exist for HMS *Buffalo* in the Whitianga Museum's collection. A difference between *Endeavour* and *Edwin Fox* is the latter has two layers of hull planking. These two layers were fastened to each other and to the internal frames of the ship. A layer of metal sheathing then covered the second outer layer. Their averaged dimensions are summarised in Table 43. For the purpose of discussion, only maximum recorded dimensions have been included and calculated to indicate the average maximum dimensions.

Table 43. Average dimensions recorded for outer planking.

Ship	**layer**	**Max width average (mm)**	**Max average thickness (mm)**	**Max length (mm)**
Endeavour	1	268.25	99.33	None recorded
Buffalo	1	None recorded	None recorded	None recorded
Edwin Fox	1	277.30	63.15	None recorded
	2	250	77.60	6390

Endeavour's single layer of outer planking shows the planks averaged 268.25 mm wide by 99.33 mm thick. These timbers were sawn from elm trees. The thickness of the planks is close to four inches, which is the normal contractual requirement for ships of similar dimensions and age to *Endeavour* ([BL] L.R.264.b.3:300). This confirms the historical record while informing us of the timber used for the vessel's outer planking.

No contracts could be found for ships similar to *Edwin Fox* and thus the dimensions presented here provide an insight into developing planking dimensions. The first layer of hull planking measured an average 277.30 mm wide by 63.15 mm thick and were milled from teak. The second layer of hull planking measured an average of 250 mm wide by 77.60 mm thick and was converted from elm trees. This second layer of planking is not a continuation from the original build with the 'doubling' occurring c.1869 ([LRF] LRF-PUN-LON654-0092-R). Thus, the archaeological recording probably reflects this last repair to the ship.

The planking thickness, however, has decreased compared with *Endeavour*'s average planking thickness. The other apparent change is the use of different wood for the same function. The teak planking used on *Edwin Fox* is nearly half the thickness of *Endeavour*'s outer planking. *Edwin Fox*'s second layer of outer planking is slightly thicker than the first, however, it is still thinner than *Endeavour*'s outer hull planking. It is argued here that over time, individual planking thicknesses have decreased. Although having two layers of outer planking significantly increases the overall wall thickness of the hull. The functionality of *Edwin Fox*'s double hull planking is explored later in this chapter.

8.2.3.8 Sacrificial outer planking

Sheathing boards 'were a very necessary protection for the ship's hull in hot climates against the insidious attacks of the worm' (Chatterton 1912:82). *Endeavour* and HMS *Buffalo* both recorded sacrificial sheathing planks. These were fastened to the outside of the hull planking with metal sheathing attached to their outer faces. These thin (c.24 mm) timber planks served as additional protection to the outer planking on the ship's hull while allowing for efficient repair when necessary. Due to several planks being recorded for each vessel, their maximum widths and thicknesses are averaged for discussion (Table 44). The lengths are not discussed here because no maximum measurement was recorded.

Table 44. Recorded dimensions of sacrificial sheathing.

Ship	Max average width (mm)	Max average thickness (mm)	Joints
Endeavour	208	27.25	Possible scarf
HMS Buffalo	209	24.8	Possible butt
Edwin Fox	None	None	None

Each plank had varying levels of degradation, with their ends broken and faces weathered. There is an average of 1 mm difference in widths and approximately 3mm in thickness between the two vessels. These minimal differences are possibly linked to varying conditions of the timbers caused by inadequate conservational treatments or by variation in the original milling process. Therefore, the plank's widths and thicknesses probably remained the same over time when employed as sacrificial timber sheathing.

Furthermore, *Endeavour*'s planks were milled from teak and pine while HMS *Buffalo*'s timber sheathing was identified as cedar. The teak in *Endeavour* could be related to repair work after the vessel was sold from the Company's service and continued sailing around India, whereas the pine was probably originally sourced from stockpiles in Britain. Baltic pine was imported into India, but only occurred in the late-nineteenth century with the widespread building of its railways and demand for timber sleepers (Costley 2014:220–221).

Softwood was chosen specifically to function as sacrificial timber sheathing. Archibald Cochrane (1784:4) described using softwoods like fir as a method to combat shipworm because the wood's open pores allowed tar to 'penetrate to a considerable depth'. Thus, the choice of timber was a conscious decision for creating the best protective barrier for a ship's hull, while simultaneously preserving more significant timber stocks, like oak.

The source of HMS *Buffalo*'s timber remains undetermined and it is unknown when the cedar was last applied, although it was probably attached when the ship was re-sheathed. The average lifespan approximated for copper sheathing in the early nineteenth century was three to four years (Marquardt 2003:139). The ship would have been sheathed in metal multiple times over its life, including replacing the layer of sacrificial timber. The use of cedar and pine tells us how sacrificial timber was chosen, using timbers that were otherwise unsuitable for the hulls' structural rigidness.

Edwin Fox did not have an outer layer of sacrificial timber sheathing fastened to the hull at the time of archaeological recording. A *Report of Survey for Repairs; Change of Owners &c for Edwin Fox, 8th July 1854*, however, recorded the ship's 'bottom has been sheathed with wood over felt from keel to wales, the wood sheathing caulked and covered with yellow metal sheathing' ([LRF] LRF-PUN-LON635-0031-R). Thus, according to the historic record, *Edwin Fox* was probably originally constructed with one outer layer of hull planking and a layer of sacrificial timber planking. Over the ship's life, this was removed and replaced for repair. Then around 1869, the timber sheathing was not replaced, and the second diagonal planking layer added instead ([LRF] LRF-PUN-LON654-0092-R). The Muntz metal was fastened directly on to the second outer layer (doubling) of timber planking. There is no record of the dimensions of the sacrificial timber sheathing and it therefore cannot be directly compared. The metal sheathing is discussed in the antifouling technology section of this chapter.

8.2.3.9 Ceiling planking

Edwin Fox is the only ship to have confirmed ceiling planking. *Endeavour* had one possible ceiling plank (END_027) although its condition meant it was difficult to positively identify its function. Based on the recorded diagnostic features, however, it is probably a ceiling plank and is included here. Ceiling planks are absent from the HMS *Buffalo* collection used for this research. Instead, approximate widths extracted from the 1980s site plan and data presented in the results chapter are included in this discussion. The thickness, however, could not be measured as the plan view is two-dimensional. Timber dimensions are summarised below (Table 45).

Table 45. Recorded ceiling planking dimensions.

Ship	Max moulded average (mm)	Max average thickness (mm)	Max measured length (m)
Endeavour	286	63	None
Buffalo	c.300	None	None
Edwin Fox	248.84 (port), 248.63 (stb)	77.82 (port), 95.68 (stb)	20.36

Endeavour's only possible ceiling plank measured a maximum 286 mm wide by a maximum 63 mm thick. *Edwin Fox* offered both the port and starboard sides for recording, which allows for comparison between ceiling plank dimensions on each side. The average measurements for the port side are 9348.30 mm long, 248.82 mm wide and 77.82 mm thick. The average measurements for the starboard side are 10495.85 mm long, 248.63 mm wide and 95.68 mm thick. Although the port side planks are smaller than those of the starboard side, interestingly, the average width measurements for both sides are similar. The thicknesses, however, are on average slightly thinner on the port side. Overall, there is an average difference between the port and starboard sides of approximately 20 mm in thickness.

Specific to *Edwin Fox*, the ceiling planks were milled to the same standardised widths, whereas the thicknesses seem to vary. This could be caused by several factors. First, the thickness may reflect the availability of timber to be used for planking. Second, orders for the timbers may have been processed by different suppliers. Third, the thicknesses may have been affected by environmental processes whereby the timbers have dried out causing the internal cell structure to shrink during post-salvage activity. Last, thicknesses may have worn down over time, mostly caused by contemporary anthropogenic formation processes, i.e. pedestrians walking on the timbers, although this is improbable. Considering these possibilities, it is argued here that overall, the starboard side is slightly thinner than the port side, albeit with minimal difference and the widths appear to be standardised. Finally, when compared with *Endeavour* and *Buffalo*, ceiling planks change little over time with similar dimensions carried through the industry. Variation is probably the result of resource availability and subsequent milling techniques.

8.2.3.10 Summary

When assessing differences and similarities over time, dimensions of the timbers do not change significantly. Whereas subtle changes probably reflect the scantlings being proportional to the overall hull dimensions (length and breadth). In more detail, however, the individual timber components reveal differences when investigating ship construction. Specifically, the difference in choice of wood demonstrates the shift to adopt foreign timber resources for ship construction. Even with this adoption of new timber resources, the scantling dimensions from the late-eighteenth to early-nineteenth centuries suggests British shipbuilding scantling dimensions continued without innovation towards the new product. It is between the early to mid-nineteenth century that we see the thicknesses of hull planking reduce and is possibly a result of colonial shipwrights accepting the ‘superior’ qualities of teak versus the domestic product on which they learned.

8.2.4 Fasteners

Ship fasteners are a central element that provide significant insight into the world’s boat and shipbuilding traditions (McCarthy 2005:3) because they demonstrate changes in technology. Several different types of fasteners are recorded in the timbers of *Endeavour*, HMS *Buffalo* and in the preserved hull of *Edwin Fox*. The types of fasteners include treenails, pegs, ferrous and non-ferrous bolts and nails and sheathing tacks. These fasteners joined major ship timber components together and attached protective hull layers. The combination of these fastenings helped ships to counter external forces acting on the hull and subsequent distortions whilst sailing through waves and swells (McCarthy 2005:3).

8.2.4.1 Treenails

Extant wooden treenails were recorded in all three ships and are summarised in Table 46. Michael McCarthy (2005:25) defined a treenail’s function as fastening planking to the ship’s frame timbers. The treenails recorded for this study were evident in the ceiling planking, outer hull planking and futtock timbers. The treenails varied in preservation but revealed the types of treenails used in joining timber components together, including the types of wedges (Figure 119).

Table 46. Treenail diameters summarised for *Endeavour*, HMS *Buffalo* and *Edwin Fox*.

	Endeavour	***Buffalo***	***Edwin Fox***
Treenail no wedge	34–43 mm	30 mm	25 mm (plug), 30–38 mm (treenail)
Treenail with straight wedge	30 mm	None	30–38 mm
Treenail with cross-wedge	None	None	33–34 mm
Treenail with triangle wedge	None	None	33 mm
Treenail with square wedge	40–41 mm	None	None

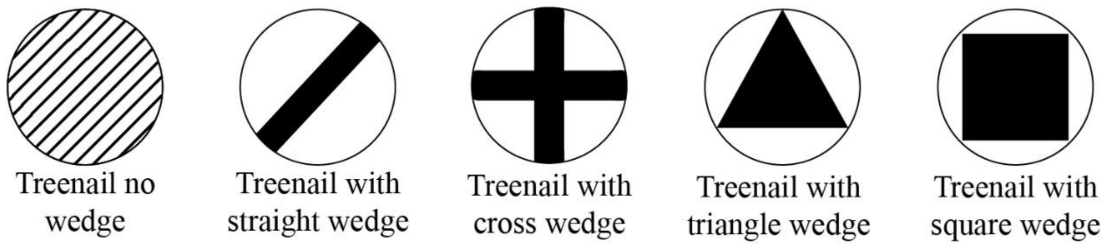

Figure 119. Recorded treenail types.

Diameters of the treenails used in the three ships are similar over time. *Endeavour*'s treenails measured between 34 mm and 43 mm in diameter. HMS *Buffalo*'s treenails measured c.30 mm in diameter and *Edwin Fox*'s treenails measured between 30 mm and 38 mm in diameter. This indicates the transference of existing treenail standards across time. This sizing also probably reflects the diameter of the auger used to drill the holes as it was easier to shape a timber treenail to fit a mechanically made hole. Therefore, tools, such as the auger, used in the art of shipbuilding are likely to have remained the same over time.

Due to the condition of the disarticulated timbers in the *Endeavour* and *Buffalo* collections, evidence of wedges used in securing the treenails varied. In *Endeavour*'s construction, however, both straight wedges and square wedges were used in the assemblage. The use of the wedges demonstrates the application of two different methods for securing the planking to ships' framing.

Edwin Fox, being a preserved hull, recorded the use of several different wedges for both the ceiling and second outer layer of hull planking treenails. On the ceiling planking, straight and cross-wedges were used to flare out the tops of the treenails, whereas on the outer hull planking, a triangle shaped wedge was used to secure the treenails (Figure 120). The origin of the triangle wedge is unknown; however, their use is evident in British domestic shipbuilding practices with triangle treenail wedges also recorded on *Jhelum* (built 1849) (Stammers and Kearon 1992:82–83). The distribution pattern of treenails reveals they are commonly used from planks CS5 up to the gunwales. The planks closest to the keelson are fixed to the underlying floor and futtock timbers with ferrous metal fasteners. It is unknown if the treenails observed from the outside extend to the inside of the hull.

The use of treenails in colonial shipbuilding is highlighted by Ball (1995:53):

> Treenails were not favoured in the warmer climates as it was observed that treenails shrink when exposed to the 'rays of the tropical sun'—allowing water to seep in and rot the timber.

Considering this insight, it is surprising to think that with *Edwin Fox* being built in a warmer climate, shipwrights employed treenails as a fastening technique. The treenails, however, were never exposed to daylight during its sailing career because the hull was covered with a layer of pitch and metal sheathing below the waterline. This demonstrates the technology of treenails was still employed up until the at least the mid-nineteenth century in British merchant vessels. In addition, there was no need for the technology to develop further considering the treenail diameters remained consistent over time. Treenail knowledge employed in domestic shipbuilding during the late-eighteenth century continued through into mid-nineteenth century colonial shipbuilding.

Figure 120. Triangle treenail wedges (centre) on the second planking layer on *Edwin Fox*, port side (2017).

8.2.4.2 Treenail pegs

McCarthy (2005:66) argued that wooden pegs can equally be described as treenails, but in this study they are distinguished differently. This is because wedges can identify the presence of a treenail, 'treenail pegs' (with no wedge) equally serve the same function. Treenail pegs are used here to differentiate between the noticeable difference in recorded diameters between the timber fastenings and an absence of wedges. Thus, wooden pegs recorded in all three vessels were identified by their small diameters and having no evidence of wedges. They measured between 15 mm and 25 mm in diameter. Their lengths, however, were not recorded due to being secured in their parent timber component. This inaccessibility also made it difficult to determine the form and function of the pegs themselves. The pegs were probably used to fill holes made by rusted out ferrous fasteners or to aid the shipwright as a guide/place holder when forming and fastening the planking with larger treenails and/or metal bolts.

8.2.4.3 Dumps

Dumps, also known as ‘bolt nails’, are described as short round bolts with long flat points (McCarthy 2005:84). It is likely that dumps were used for fastening the ceiling planking to the futtocks in *Edwin Fox*’s hull. There are one or two dumps where each plank end abutted another (Figure 121). There did not appear to be a pattern to their use, although their function is identified as securing the ends of the planking during construction. These types of fasteners remained in use until the latter half of the nineteenth century, although they did present problems. A Royal Navy experiment between 1834 and 1848 that used of dumps in replacement of treenails found that dumps were overall heavier, had less holding strength and caused the ends of planks to split (McCarthy 2005:84). This is probably the reason the archaeological evidence for dumps indicates that they were employed sparingly throughout the hull. Furthermore, there was no evidence of splitting around the dumps. Therefore, teak timber may have been suitable when using these types of metal fastenings.

Figure 121. Dumps used for fastening ceiling plank CS5 in the *Edwin Fox* hull (2020).

8.2.4.4 Clinched bolts

Iron bolts with washers were used to secure the limber strakes, thick strakes and ceiling planking in *Edwin Fox*. These fasteners are probably bolts with clinch rings. The positioning of these bolts along the ceiling planking of *Edwin Fox* appeared to be irregular. Impressions recorded on the *Endeavour* timbers indicate possible iron clinched bolts were used; however, no extant bolts remained for identification. As was the case with dumps, clinched bolts served to fasten the ceiling planks inside the *Edwin Fox*'s hull and were used in combination with treenails. Thus, proving a mixture of fastener types was employed for the construction of *Edwin Fox*.

8.2.4.5 Iron nails

Iron nails were recorded on both *Endeavour* and HMS *Buffalo*. The iron nails were either heavily corroded or broken at the time of recording, so their lengths could not be measured. Their use, however, in the outer planking and the sacrificial timber sheathing indicate the iron nails were possibly used as holding nails while other copper nails were driven through the timbers. The shipwrights were probably unaware of the theory of electrolysis and the effects of mixing ferrous and non-ferrous metals below the waterline (Jones 2004:89; Marquardt 2003:139).

Additionally, the use of iron fasteners which would have been covered by the copper sheathing may be a result of economics in the shipyard. Iron nails were less expensive than copper nails and may have been used by the master shipwright to keep costs down. Although the sacrificial sheathing contained mostly copper tacks, iron nails were used for fastening the plank to the outside of the hull.

8.2.4.6 Staples

Both *Endeavour* and HMS *Buffalo* exhibited evidence of possible staples used in fixing the false keel to the keel, whereas *Edwin Fox* had no evidence of this technology. The false keels of *Endeavour* and HMS *Buffalo* contained holes which are probably associated with metal staples, but no staples were recorded in situ. The Mercury Bay Museum and Southland Museum and Art Gallery Niho o te Taniwha, however, have in their respective ship collections, metal staples that are similar in size and shape to the holes recorded on the false keels (Figure 122 and Figure 123). While not recorded in the context of the false keels, the two staples indicate changes in manufacturing and fastening ideology. The *Endeavour* staple is barbed, possibly through the process of ragging, to increase its holding strength, and appears to be manufactured using manual techniques (McCarthy 2005:179). On the other hand, HMS *Buffalo*'s staple is more robust and is probably machine moulded. The two staples show that over time, the same fastening method employed in the assembly of the hull with refined manufacturing processes.

Figure 122. *Endeavour* staple held in collection at the Southland Museum and Art Gallery Niho o te Taniwha (after photograph: Kimberley Stephenson, April 2019).

Figure 123. HMS *Buffalo* staple on display in the Mercury Bay Museum. The bend is probably caused by modern salvage processes.

8.2.4.7 Keel bolts

Keel bolts used in *Endeavour* extended through the keel and false keel timbers. The bolts measured between 32 mm and 33 mm in diameter and they were spaced 1,330 mm apart centre to centre. *Edwin Fox* exhibited ends of what might be copper alloy keel bolts supported by a washer. These were observed in the outer face of the false keel. Although the length could not be measured it is highly probably that these bolts extend through the main keel assembly. Furthermore, *Edwin Fox*'s identification compares to the diameters and form recorded in *Endeavour*'s keel.

The use of metal alloy keel bolts remains similar with its manufacturing origins from the late-eighteenth century through to the mid-nineteenth century. In July 1783, William Forbes took out a patent for ships' bolts and fastenings produced using copper and copper alloy through grooved rollers (Harris 1966:557). The continuation of copper alloy ships' bolts demonstrates the transmission of the technology across global geographic areas with the influence of domestic technology on foreign colonial shipbuilding industries.

An interesting feature of the keel bolts recorded in the *Endeavour* collection is the 'flowering' of the bolt's heads, indicating the heads were splayed out by force when installing the fastener. Adams (2013:156) noted that copper and iron was more malleable than copper-alloy fasteners—the former needing to be driven into the timber assembly with a wooden mallet. The introduction of a new fastener technology is likely to cause some unfamiliarity with shipwrights and potentially some understandings of what tools were best to drive the bolt into the keel assembly. The 'flowering' probably reflects a worker using an iron hammer to install the bolt. Similar evidence relating to a worker's unfamiliarity when working with copper-alloy bolts is found in the archaeology of the colonial shipyard, Deptford, in Aotearoa New Zealand (Carter 2019:198). Equally, the 'flowering' of the fastener head could be an intentional action by the worker to cause the bolt to fasten or clamp the timbers together.

8.2.4.8 Copper alloy fasteners

Copper alloy fasteners were recorded in the outer planking of *Edwin Fox*. These are positioned alongside some of the treenails with triangle wedges, although less frequently. The type of bolt could not be identified; however, they measure 25 mm in diameter. This indicates they maybe a type of dump or spike. The material analysis showed a mixture of metals, used to make the fastener stronger. The use of copper alloy fasteners is common in ships as it was a further precaution against corrosion in iron fastenings caused by salt water. The use of copper fasteners was known in the eighteenth century with country-built ships, like *Diana*, fastened with iron and copper bolts. No other comparable copper alloy bolts or dumps were recorded in the collections of *Endeavour* and HMS *Buffalo*.

8.2.4.9 Sheathing tacks

Tacks are used on the three case studies to attach metal sheathing to the outside of the ships' hulls. McCarthy (2005:175) described these fasteners as 'very small nails' measuring c.40 mm in length that fasten metallic sheets to the outside of a ship's hull. Equally, Richard Meade (1869:400) described the fastening of sheets with '...mixed-metal nails called sheathing nails'. Sheathing tacks recorded from the three case studies displayed similar dimensions with variations up to 34 mm in length (Table 47). The apparent differences between the tacks are the shapes of the shanks and methods of manufacture (Figure 124). *Endeavour* contained sheathing tacks with square shanks with sometimes irregular shank sizing and hammered heads. It is probable that these tacks were manufactured using the wire cut process, which was a common practice for producing tacks towards the end of the eighteenth century (McCarthy 2005:175). By the early nineteenth century, manufacturing processes improved, as the evidence from the HMS *Buffalo* sheathing tack shanks shows it was a machine-based process. McCarthy (2005:175) also noted that by 1815, the heads were also machine made. Then by the mid-nineteenth century, and with the introduction of the new copper alloys, the sheathing tacks from *Edwin Fox* show a rounded shank with a refined point. The entire tack was not produced in the same mould, however, as the counter-sunk head was applied at a later stage. Archaeological evidence from the three case studies display modification in the manufacture process as well as adoption of new innovations which helped to further refine the application of an antifouling technology. There is a clear shift from a labour-intensive process to a mechanised manufacturing process.

Table 47. Sheathing tack dimensions.

Ship	**Length (mm)**	**Diameter (mm)**	**Shank shape**	**Head application**
Endeavour	<34	<13	Square	Hammered
Buffalo	<33	11	Square	Applied
Edwin Fox	31–45	12	Round	Applied

Figure 124. *Endeavour* (left), HMS *Buffalo* (centre) and *Edwin Fox* (right) sheathing tacks.

8.2.4.10 Summary

Treenails are the type of fastener used most consistently in all three ships. They are used to fasten both outer and ceiling planking to the floor timbers and futtocks of the vessels. Their diameters remain similar and demonstrate limited refinement over time for this type of hull fastener.

Iron fasteners were used inside the hull to secure the planking to the futtocks. The types of fasteners employed indicate their intended function in the shipbuilding process. The ‘possible’ dumps secured the ends of the planks, sometimes using one or two. Other iron bolts with clinched heads were spaced at irregular intervals along the planks. This is probably to fix the plank in place while letting the drilled holes for the treenails air out—a technique proposed for seasoning the ship while under construction to increase its length of service (East India Company 1810:24).

In the practice of shipbuilding, alloy fasteners were also used below the water line on a ship’s hull. As evident in the hull of *Edwin Fox*, copper alloy bolts are used alongside treenails to fix the second outer layer of planking to the hull. The use of alloy fasteners below the waterline decreased the risk of the ship’s hull breaking apart because they corrode more slowly than iron fasteners. Therefore, keel bolts were manufactured from alloy metals to ensure the most important parts of the ship remained affixed when at sea.

The major difference between the vessels is the discontinuation of the sacrificial timber sheathing and the associated fasteners. Iron and copper square nails were used to fix the sacrificial planks to the outside of the ship’s hull. *Edwin Fox*, however, lacks sacrificial planking and therefore iron nails are absent in the hull planking below the waterline. The metal sheathing has been applied directly to the outer layer of hull planking with copper alloy tacks. *Edwin Fox* was originally sheathed with sacrificial timber; however, this was removed when the second layer of hull planking was attached. Therefore, it is probable that sacrificial timbers became less important due to the addition of a second layer of hull planking applied diagonally. Finally, the continuation of using traditional fasteners confirms shipwrights relied on prior learned knowledge for vessel manufacture. The adoption of new metal fasteners, however, demonstrates shipwrights were experimenting with new materials in an attempt to advance ship development.

8.2.5 Waterproofing technology

Several methods of waterproofing ships' hulls were recorded within the three case studies. These methods include caulking, plank lining, sheathing underlay and pitch. Each of these contained either fibres and/or resinous pitch-like compounds. The results from the fibre identification and pitch sample analyses are discussed below.

8.2.5.1 Caulking

Endeavour and *Edwin Fox* contained fibrous caulking in the seams between planks. Notably, caulking in *Endeavour* was evident along the rabbet where the garboard strake would fit against the keel. *Endeavour*'s caulking consisted of goat hair matted together in a cylindrical shape, whereas *Edwin Fox* had packed strands of hemp. Both fibres used in the two ships' hulls functioned the same by providing watertightness between the seams where timber components joined with each other. The origin of the goat hair and hemp could not be determined. The difference in hair and fibre does give insight into different materials employed for the same function. Both goat hair and hemp appear to be adequate for creating a watertight seal. This is reflected in the fact both ships had long sailing careers, with *Endeavour* being abandoned through old age and *Edwin Fox* reused for several purposes before becoming a static museum display.

The different fibres used in the hulls over time give insight into the economies of this material for waterproofing. For example, *Edwin Fox* demonstrates the use of hemp as a caulking material and probably reflects the economies of procuring and securing the fibre for shipbuilding. Hemp, however, was also imported from other European powers to Britain around the turn of the nineteenth century. Hemp supply during the 1790s to 1800s was under political control from foreign powers. On 10 October 1800, the Board of Directors at the East India House wrote to the Governor General of Bengal stating that European hemp prices had increased since 1792 from £23.10 to £61 per ton (Bulley 2000:97). Russia was an exclusive supplier and therefore controlled the pricing on the international market. Britain was in no position to cultivate hemp domestically as it would take away land area for other agriculture. On the other hand, British colonies like India provided relief on demand for shipbuilding materials. In response, two hundred acres of hemp was planted and grown in Bengal (Bulley 2000:97). After trials c.1800, the Indian grown hemp was found to be inferior to that of the European variety. The hemp ropes used in rigging stretched (Bulley 2000:98). At the end of the Napoleonic War, however, the Russian hemp supply was again secured and there was no establishment of the Bombay hemp export industry (Bulley 2000:100). The security of this trade supply was always governed by market conditions and conflict. Therefore, Britain needed security of shipbuilding materials from its own colonies.

8.2.5.2 Plank lining

A fibrous compacted matting exists only on *Edwin Fox*. This is located between the two layers of hull planking. The fibres comprise compacted goat hairs forming a layer that is dense, resembling felt. There is no evidence of it being applied with a tar-based compound. Instead, it exists as loose sheets most probably applied at the same time when the outer layer of hull planks was fastened to the inner layer of hull planking. The function of this lining is likely to increase waterproofing capabilities of the hull by adding another layer of material between the sea and the hull's interior. The choice of goat hair is consistent with the choice of fibre for caulking on *Endeavour*, approximately 70 years earlier, although for a different function. Furthermore, *Edwin Fox*'s second layer of hull planking was applied in 1868 and the fibrous matting was probably applied at the same time (Costley 2014:222). Therefore, the application of this fibrous layer reflects a British adaptation incorporated into colonial-built vessels and a continuation of the sheathing underlay technology used in earlier vessels.

8.2.5.3 Pitch

The Columbia Electronic Encyclopedia (2016) described tar and pitch as dark brown to black substances created through the destructive distillation of coal, wood, petroleum, peat and certain other organic materials. The heating and/or the partial burning of wood to make charcoal was the main method prior to the introduction of petroleum; with historical sources often referring to pitch or tar only. Since the Tudor period, various combinations of solutions and poisons were 'payed' to the hull (Goodwin 1987:226). A compound, invented by Lee, a Master Caulker at Portsmouth Dockyard in 1737, consisted of pitch, tallow and sulphur (Goodwin 1987:226). The mixture aided burning off marine growth when ships were careened. In 1780, the Earl of Dundonald 'discovered a new and easy method of extracting tar from coal' (Cochrane 1784:3) and an Honourable East India Company ship's tender dated c.1786 stated that it would use 'hot tar' in the process of sheathing a ship ([BL] L.R.264.b.3:305).

Furthermore, the compound could include several different ingredients including lamp-black, volatile alkali, sal ammoniac, Glauber's salt, fossile alkali (sodium carbonate) and barilla (Wilkie 1785:376). Peter Goodwin (1987:226) discussed using such compounds before the metal sheathing in the context of English warships. A compound of tallow, horsehair and sulphur applied to the hull with the thought that the fibres would choke the *Toredo navilis* (shipworm) as it bored through the timber. The tallow was used as a binder and the sulphur used as a toxin against the shipworm. In the past, various organic hull compounds have been described as 'black stuff', 'white stuff' and 'brown stuff' without being specific to their mixtures. Brian Lavery (2017:262) described these mixtures, with black stuff being a mixture of tar and pitch; white stuff consisting of train oil, turpentine and sulphur; and brown stuff a combination of tar, pitch and brimstone. Additional sources like Isaac Blackburn's (1817:181) treatise described the geographic differences between pitch compounds. He noted a mixture of fish-oil and lime, called chunam, is used in the East Indies and presented qualities as a preservation for iron and copper. In Surat, dammar, a tree gum, is used instead of pitch and in Bengal a mixture of lime, fish-oil and sugar was used.

The process of applying pitch was a dirty job. Goodwin (1987:227) in an eighteenth-century naval context referred to applying a sheet of something before the copper sheathing as 'papering'. It was a messy and hazardous job with the workers getting covered with pitch, especially working on the undersides of the hull. Basil Greenhill (1988:156) described applying the pitch as 'paying up' using mops. The workers suffered burns to the face and neck, many resulting in burn blisters. A mixture of fibres and resinous substances were applied between the ships' most outer layer of hull planking and the metal sheathing.

The chemical results of the three case studies varied, with the inclusion of fatty acids, resin acids, waxes and hydrocarbons. These elements are seen in various natural oils and binders. Long chain fatty acids include compounds such as palmitic acid, stearic acid and myristic acid. The combination of these acids is found in palm oils. P-coumaric acid is a naturally occurring product and can be observed in its diester form as a component of carnauba wax. Methenamine is used in phenolic resins as a hardening agent and are typically used as a chemical binder. Dehydroabietic acid is naturally occurring and is derived from woody plants, specifically conifers (Wilkins et al. 1992:1). Ancient and historical shipwrecks found in archaeological contexts have been sampled for pitch and tar compounds and analysed using GC-pyrolysis (see Beck and Borromeo 1990; Connan and Nissenbaum 2003; White and Stern 2017). A study on conifer tar on the keel and hull planking of a fifth-century BC shipwreck, concluded the pitch was made from conifer resin and through a thermal process produced a conifer 'tar' or 'pitch' (Connan and Nissenbaum 2003:717). Therefore, the organic pitch analysis from the three case studies contributes to the discussion of different pitch compound combinations used in shipbuilding.

Endeavour's hull was payed with a hessian-like matting mixed with a tar-based substance. The 1/1 plain weave is the simplest and most frequently used. Incorporating its maximum number of interlacing and binding points makes the fabric stronger and firmer than other fabrics such as the twill weave (Taylor 1991:77). This fabric was applied with a tar compound before attaching the metal sheathing. *Endeavour*'s results consist mostly of long chain fatty acids and are comparable to the pitch analysed using Computerised Gas Spectrometry from the *Mary Rose* shipwreck (Evershed et al. 1985:529). The presence of dehydroabietic acid in the *Endeavour* samples suggests the tar is likely to be made from conifers. Furthermore, methyldehydroabietate is considered a marker of pine resin. Although it is not naturally present in the tree, it forms during the thermal production process when making tar (Dimitrakoudi et al. 2011:582).

Different methods and materials from those used in Britain were employed in the shipbuilding industries in India. Anne Bulley (2000:26–27) described some of these adaptations. For example, dammer was used instead of pitch as the heat in the tropics would melt the latter. Dammer is a resin used for sealing and caulking and sometimes used as a substitute to pitch (Ball 1995:54). John Phipps (1840a:33) reveals the effects of using pine tar in tropical climates.

> I confess the reports from the Marine Department at Calcutta, are not very favourable; as the pilots declare it to be totally unfit and inapplicable for any purpose, but that of paying a ship's bends [wales]; as they state that it burnt the rope; that it would not dry on the rope, and that the blocks were immediately clogged with it.

As further protection for the hull, the bolts were coated with chunam or lime mixed with hair on top of the teak planking. Blankets boiled with dammer of tar were then applied before coppering the hull (Bulley 2000:27). A treatise described *Duncan*, 'the first [British] ship built on the Malabar Coast (in 1803)' using teak timber and materials produced from its territories, with its tar extracted from the [teak] chips and saw-dust laying around the yard (Phipps 1840a:174).

HMS *Buffalo*'s results were compared to dammar and no similarities were found (Jamal et al. 2015). HMS *Buffalo*'s pitch samples indicates that it was a hydrocarbon-based tar. The vessel's tar is therefore likely to have been created through the thermal process of heating coal and natural oils. In addition, there is a presence of sulphur, which is naturally occurring and likely to be associated with the hydrocarbon compounds. P-coumaric acid, palmitic acid and dodecanoic acid also suggests the inclusion of wax-based substances and plant-oil extracts included in the pitch. Therefore, this compound probably reflects British practices as the ship was last sheathed at Chatham Dockyard c.1833.

Edwin Fox's pitch included retene, which is an indicator of pitch being created from pine wood (Dimitrakoudi et al. 2011:582). This pitch, however, is unlikely to be exclusively made from conifer trees. This is because of the presence of Benzene, which is found in coal tar. Additionally, the presence of waxes and azulene suggests the inclusion of plant-based oil components. *Edwin Fox*'s pitch was mixed with loose fibres, unlike the woven material applied to the *Endeavour*'s hull around 70 years prior. This suggests shipwrights were substituting woven fabrics for several loose plant fibres to be included in the tar-based compound. The discontinuation of woven cloth is likely linked to economising the shipbuilding industry, replacing the cloth with cheaper more readily available oddments leftover in the shipyard. What is unknown, however, is whether the two different mixtures of materials proved as effective. It is argued here that the organic compound on *Edwin Fox* was effective as a protective agent—as the vessel was refloated in the 1980s with modern aid (Costley 2014:179–180).

When assessing the three case studies of pitch, there is a shift from exclusively plant-produced pitch to the addition of hydrocarbons derived from coal. During the early to mid-eighteenth century, pitch and tar imports to Britain rose from 30,000 barrels and exceeded 100,000 barrels around 1770—the Navy's average consumption was between one quarter to one third of the total volume of imports (Kirby 1974:97). The rest was probably used in the merchant trade, including the construction of the Company's ships. During this time, Britain had global connections, importing tar from its American colonies and securing stock from Sweden, known as Stockholm tar (Kirby 1974:100). Wars during the eighteenth century pressured the Navy's board to consider securing future supply. In particular, the American War of Independence and subsequent loss of Britain's American colonies and tar supply meant the island nation had to return to trading with other European countries (Kaye 1997). By the early nineteenth century, the introduction of coal tar in ships' pitch suggests Britain's ships' stores were adopting new materials for pitch rather than relying on foreign supply. Thus, domestic coal deposits may have contributed to the continued security and supply of pitch for British shipbuilding.

It is possible that HMS *Buffalo* and *Edwin Fox* did have a local pitch used in India applied to their hulls shortly after launching. The process of resheathing the ship, however, involved removing all previous pitch before a new coating was applied, with both vessels resheathed several times over their working lives. Thus, the pitch reflects the last time the vessel was sheathed and more so reveals pitch compounds used in British shipyards rather than colonial shipyards.

8.2.5.4 Summary

The analysis of the three ships resinous compounds sheds light on the technological development of the organic and fibre compounds applied to the outside of the ships' hulls for caulking and before metal sheathing. The consistent inclusion of pitch in the compounds demonstrates a belief that it was an essential product for 'paying' the hull. The inclusion of other fibres and plant organics highlight different materials used for packing out the compounds. The shift from using woven wool in the late eighteenth century to using scraps of organic matter in the mid-nineteenth century suggests a strong woven matting was not needed in warding off the ship worm. Furthermore, it reflects the shipwright's abilities to adopt to the changing economic and political environments of the shipyards and resource availability.

8.2.6 Antifouling technologies

This investigation contributes to the study of ship metal sheathing by understanding the technology adopted in the British merchant shipping industry, specifically around the turn of the nineteenth century. All three primary case studies presented evidence of antifouling technology in the form of metal sheathing and indicate the technology was in use since at least the 1780s on BEIC vessels. Analysis of the individual sheets reveal valuable insights into the development of the industrialised process of manufacture and metallurgy. Information gleaned from metal composition, size of the individual sheets, sheeting patterns and fasteners used for nailing the sheets to the outside of the hull contribute to understanding the development and application of metal sheathing as an antifouling technology. A comprehensive history on the development of ship metal sheathing has been widely published in previous years (see Bingeman 2018; Bingeman et al. 2000; Harris 1966; Staniforth 1985; van Duivenvoorde 2015b).

The first official introduction of copper sheathing used on a British naval ship was trialled on *Alarm* in October 1761 (Lubbock 1950:27; Staniforth 1985:23). It then took the remainder of the century for complete adoption of metal sheathing. On 23 April 1800, William Collins was granted a patent for 'an invention of a preparation or application of sundry articles and materials to be used chiefly for the preservation of shipping or marine purposes' and he categorised his sheathing based on colour (Webster 1844:86). The first was red sheathing, which consisted of copper into which a portion of zinc, or tin, or other metal or semi-metal was mixed at a ratio of 'eight parts of copper to one part zinc' (Webster 1844:86). The second was yellow sheathing, comprising a mixture of 'one hundred parts copper and eighty of zinc' (Webster 1844:86). The third was white sheathing, 'which consists of tin, lead, zinc, copper, regulus antimony, or say other metal, or semi-metal' (Webster 1844:86). Overall, however, Collins recommended using 16 parts zinc, 16 parts tin and one part copper to ‘form a good mixture’ (Webster 1844:86). Then around 1830, bronze ship sheathing was trialled on Falmouth packet ships. It was thought that the use of bronze sheathing consisting of copper with six to ten per cent tin was adopted from the French Navy after trials in 1829 (Anon. 1834). This bronze sheathing, while successful in trials was not entirely adopted due to its high price—costing 2d. per pound more than copper (Anon. 1834). It was around this time that a different ship sheathing consisting of copper and zinc was introduced. The development of Muntz metal produced a material that was cheaper than pure copper, while maintaining the toxic properties necessary for protection against marine growth and shipworm (*Teredo navalis*). Thus, sheathing technology developed from using pure copper to a mixed copper alloy, more commonly known as Muntz metal or ‘yellow metal’.

The composition of the three case studies’ sheathing samples show changes in elements used in their manufacture and reflect the development of the technology over time (Table 48). The results highlight that pure copper sheathing was used for both *Endeavour* and HMS *Buffalo*, whereas *Edwin Fox* was sheathed using Muntz metal. This adoption of sheathing materials reflects the historic record and development of antifouling technology.

Table 48. Hull sheathing metal composition and sheet dimensions.

	Endeavour	***Buffalo***	***Edwin Fox***
Composition	85.03–90.63 % Cu: 9.37–15.53% C	80.34–85.93% Cu: 14.07–19.66% C	63.52–66.22% Cu: 33.63–35.75% Zn: trace elements of Pb
Sheet length (mm)	1401	1200	1210
Sheet width (mm)	Incomplete	Incomplete	353
Sheet thickness (mm)	0.9	1	1.1

Both *Endeavour* and HMS *Buffalo* were sheathed using pure copper sheets with higher than expected percentages of carbon. The presence of carbon is not a consequence of the sample preparation process whereby previous ship metal analyses covered their samples with carbon (Carlson et al. 2011:113). The carbon inclusions probably result from the smelting process and/or the manufacturing process. For example, the smelting of tacks in Anglesey consisted of pouring copper-zinc alloy, with added tin, into ‘ash and clay molds’ with the ash possibly contaminating the metal composition (Ciarlo et al. 2016:273). Andrew Marr (2006:74) described smelting processes as placing raw ore into a heat source with charcoal. It is also possible that charcoal was used as an agent to combine processed copper flakes before being poured into moulds. In an experiment to test the immersion of copper bolts and ship sheathing, David Mushet (1835:445) described adding copper fragments to charcoal, whereby after 'high heat' the flakes of copper were 'welded together without fusion and were soft and extremely flexible'. He then continued by saying that the metal was melted down with charcoal and poured into iron moulds. The exact cause for the carbon inclusions in the *Endeavour* and HMS *Buffalo* sheathing samples is not known. It is possible, however, that carbon was mixed with copper during the smelting and/or refinement process before being rolled into sheets. The inclusion of carbon also probably resembles the early development of metal refinement whereby the final product was not guaranteed to be rid of impurities.

Edwin Fox's metal sheathing is confirmed to be Muntz metal through the identification of the sheathing stamp and the metal composition analysis. In 1832 George Fredrick Muntz senior patented (patent 6325) a copper alloy consisting of Cu:Zn with a preferred proportion of 60:40, but it could vary from 50:50 to 63:37 (Anon. 1833:128, c.1932; Carlson et al. 2011:109). Then in 1846, patent 11410 was issued to George Fredrick Muntz senior for a new sheathing formula consisting of Cu:Zn:Pb and proportions of 56:40.75:3.25, with a note that Cu and Zn percentages can be higher or lower (Carlson et al. 2011:109). This interpretation allows for the variation seen between the analysed results and the originally stipulated patent proportions through the act of modern corrosion processes. The analysed results here are unlikely to directly match historical percentages as the metal can change due to corrosion over time. As described by the Muntz Metal Company (Anon. c.1932:29), 'in 70/30 brass, copper dissolves by preference. In brasses with less than 60 per cent. of copper, zinc dissolves by preference, leaving an approximate residue of 61 per cent. copper, 39 per cent. zinc', thus affecting the contemporary composition of the metal for analysis. This was noted after metal analysis on HMS *Sirius* with variations in composition (MacLeod 1994:139–141). The inclusion of all three elements—copper, zinc and lead—suggest *Edwin Fox*'s sheathing was probably manufactured using the Muntz metal 1846 patent.

Edwin Fox's sheathing displayed a Muntz Patent stamp reading 18 in the centre with 45 on either side. The central number indicates the weight of the sheet at 18 ounces per square foot while the meaning of the outer rim numbers remains unknown. It is assumed these numbers reflect an internal manufacturing code or other mills licensed to produce Muntz metal. Staniforth (1985:28) described how lighter sheets were placed at the stern with heavier sheets at the front—protecting the areas of the hull exposed to greater rates of abrasion. The Muntz sheet with the patent stamp was positioned aft of midships and close to the keel. Meade (1869:399–400) stated '32-ounce sheathing was used around the bows and for parts between wind and water, 28-ounce sheathing for the rest of the bottom and 18-ounce sheathing for the lower side of the main keel and between the false keel'. No other stamps were located to confirm this description applied to *Edwin Fox*. Exposing additional stamps meant removing the protective layer of corrosion and this was not advisable due to the risk of further degrading the ship's state of preservation. It was decided by the author not to destroy this layer and to record in situ where possible.

Stamps recorded on early-nineteenth-century sheathing help to identify where and when the ship was last sheathed. HMS *Buffalo*'s sheathing displayed several stamps with sheathing 010 showing four different markings: broad arrow/C/FE/183[3], broad arrows, 28 and Po32. From previous stamp comparisons arising from John Bingeman's (2018:3–7) research, HMS *Buffalo*'s hull was coppered in Chatham Dockyard in 1833 using naval copper sheathing weighing 28 ounces per square foot. The broad arrows indicate the vessel was sheathed using material that was manufactured for the Royal Navy. The anomaly, however, is the stamp 'Po32'. According to Bingeman (2018:3–5), this stamp indicates Portsmouth with 32 possibly referring to the number of ounces. This contradicts the other stamp '28' interpreted as the weight (oz/ft^2) of the sheet. Around 1805, the Admiralty started to recycle copper in their Portsmouth Dockyard rolling mill, either by smelting down and re-rolling or reusing whole or partial sheets. After 1805 however, these sheets were stamped with Po, a number and a broad arrow (Bingeman 2018:5). While the two numbers '32' and '28' do not correspond with each other in terms of weight, this variation may reflect recycling methods with the Admiralty during the 1820s and 1830s. Thus, it is likely that some of *Buffalo*'s copper sheathing was recycled in

Portsmouth Dockyard before it arrived in Chatham Dockyard to be used on the ship's hull.

The difference in sheathing tack holes between *Endeavour* and *Edwin Fox* illustrates the former using the diagonal patterning consistent with the French system and the latter using a square patterning (Staniforth 1985:30). Varying distances between *Endeavour*'s holes suggests they were manually punched, as opposed to the uniform spacing of *Edwin Fox*'s tack holes. The irregularity recorded on the *Edwin Fox* sheathing is seen in the spacing between the tacks following the perimeter of each sheet. This demonstrates *Edwin Fox*'s sheathing was manufactured and prepared using a machine-based process with labourers following the holes punched in the centre of the sheet. They then employed discretion when fastening the edge of the sheet. This is different practice to the labour-intensive process observed with *Endeavour*'s sheathing. The arrangement of sheets from bow to stern recorded on *Endeavour* and *Edwin Fox* remain consistent over time. Staniforth (1985:28) described starting 'where the stern post met the keel and work forwards and upwards on the hulls from there'. This ensured sheets would not lift by force of the water when the ship was propelled forward.

Over time, the sheathing used on ships' hulls became standardised, with material composition refined to retain antifouling properties while reducing expense. There is evidence to show the sheets were being mechanically prepared before application. In addition, the patterning of the sheathing tacks demonstrates a diffusion of technique in terms of fastening the sheets to the hull. It appears over time that the British adopted and refined both application and material for use as an antifouling technology on its ships.

8.3 Exploring process

Compared to other nations, Edward Keble Chatterton (1912:185) argued that:

> the science and art of shipbuilding in England during the eighteenth century were very defective compared with France. But during the last decade of this [1790s] and including the early part of the nineteenth century, improvements were taking place.

Combining previous BEIC archaeological investigations of *Griffin*, *Brunswick* and *Earl of Abergavenny* with the three case studies presented above enhances the sample size for assessing changes during the eighteenth and nineteenth centuries. These previous three ships, however, provide limited detailed information that can be successfully compared. Table 49 summarises the extracted information from published sources and combines them with comparative data from the three case studies.

Table 49. Eighteenth and nineteenth century British merchant ship comparison using archaeological and historical data (presented in metric).

Ship	*Griffin*	*Endeavour*	*Brunswick*	*Earl of Abergavenny*	HMS *Buffalo*	*Edwin Fox*
Year built	1748	1771	1792	1796	1813	1853
Shipyard	Perry's Yard, London	Wells, Howland Dock	Perry's & Company, London	Pitcher Yard, Northfleet, Kent	Bonner & Horsburgh, Sulkea, Calcutta	Reeves, Union Dock, Sulkea
Length	32 m (105 ft)	42.06 m (138 ft)	39.62 m (130 ft)	53 m (176 ft)	36.57 m (120 ft)	43.89 m (144 ft)
Breadth	10.36 m (34 ft)	10.97 m (36 ft)	12.8 m (42 ft)	13 m (43 ft)	10.05 m (33 ft)	9 m (29 ft 8 in)
L:B ratio	3.08	3.82	3.09	4.09	3.63	4.96
Keel (SxM) (mm)	400 x 450	366.5 x 369.5	? x ?	? x 380	? x 345	440 x 345
Futtocks (SxM) (mm)	? x ?	165.5* x 192	160 x 380	250 x 330–400	155 x 212	170–570 x 280
Ceiling planking (WxT) (mm)	? x ?	286 x 63	? x ?	180–300 x 75	300 x ?	248.63–248.84 x 77.82–95.68
Outer planking (WxT) (mm)	? x 76.2–100	268.25 x 99.3	320 x 100	200–300 x 130	Unrecorded	Layer 1 = 277.3 x 63.15 Layer 2 = 250 x 77.6
Sacrificial planking type(s)	Timber sheathing and iron filling nails	Timber / copper sheathing	Timber / copper sheathing	Timber / copper sheathing	Timber / copper sheathing	Alloy metal sheathing
Fasteners	Treenails and metal	Treenails and metal	Treenails and metal	Treenails and metal	Treenails and metal	Treenails and metal
NB: *Preserved measurement, ? = missing measurements.						

Combined data from the six vessels provide several valuable insights. The first is design. The length to breadth ratios indicates vessels measuring in the range of 32 m to 42 m long are categorised as narrow, whereas the larger vessels, *Earl of Abergavenny* and *Edwin Fox* are ‘normal’ for their length to breadth ratios. The ships, therefore, retained their beamy shape throughout the eighteenth and to mid-nineteenth centuries. This probably reflects the ship’s primary function as cargo carriers.

Overall, the archaeological record reflects minimal changes in hull design. There are, however, the introduction of technologies that improved a ship’s performance. To a degree, the Company’s ship specifications dictated the vessel’s overall dimensions. The results from this study concur with Sutton’s (2000:37, 42) view that changes over time were little, with few technological advances, but she also suggested the introduction of copper sheathing was one of the greatest technological advances. Therefore, newly built ships were a product of the transmission of prior shipwright knowledge, while incorporating gradual inventiveness through the adoption of new technologies.

Early naval architecture looked to nature for inspirations in relation to hull design. William Hutchinson, an eighteenth-century mariner, argued that ships, whether designed for fast sailing or large cargoes, be built with the ship’s bottom forming arches downward instead of having long straight floors (Hutchinson 1777:14). It was thought that the form of the hull needed to be round in order to counteract hydrodynamic pressure and ensure its sailing characteristics were maintained. He concluded his thoughts by stating: ‘the swiftest fish seen in motion at sea, as well as those fowl which swim and dive in water, are all formed with their bodies rounding’ (Hutchinson 1777:14). At the beginning of the nineteenth century, hull shapes become squarer with the shift in design away from the rounded tumblehome sides.

Planners and builders of ships generally know best which form of hull suits different trades, and in William Hutchinson’s (1777:10) opinion ‘[shipwrights] make these most noble and useful machines less imperfect than they sometimes are’. It was not until the latter half of the 1700s that Gabriel Snodgrass, the Company’s chief ship surveyor, recommended a change in hull design for Company ships. He recommended East Indiamen ship design incorporate those features seen on the Bengali ships. Snodgrass, impressed by the straight-sided Bengali ships and their sailing stability, used this observation to argue against the tumblehome design (Costley 2014:21). It is not known when the straight-walled design was officially adopted, although it is likely to have been around the 1790s. Therefore, from the block coefficients of the hulls it is clear that HMS *Buffalo*'s hull is the squarest and probably reflects these 'straight sides' observed by Snodgrass. When assessing all three ships, change in design coefficients is observable around the beginning of the nineteenth century. This adoption of different design characteristics appears to be employed on its maximum threshold, creating very square-walled ships. Then, over the course of the next 40 years, the square-walled ship design begins to be refined. The adoption of the new characteristic is not abandoned entirely. As we see with *Edwin Fox*, the cross-section shape of the hull remains square, while the lines of the hull become fairer with a cleaner run. This is perhaps for hydrodynamic purposes and reflects greater scientific understanding towards naval architecture in the nineteenth century.

Vessel design and construction parameters were also governed by environmental factors. Ships sailing to India, in particular to Calcutta, needed to have a relatively shallow draft to permit their navigation along the Hooghly River. According to Ball (1995:52), *Diana* drew 4.57 m (15ft) to 4.87 m (16 ft) when fully laden. Together with the three cases studies, it shows the ships' drafts increased minimally with *Edwin Fox* measuring 5.48 m (18ft). Ships servicing river ports like Calcutta, were limited to a maximum draft. Therefore, in addition to the ship's designers and builders, the environment influenced the design parameters of the ships.

By the mid-nineteenth century there is a dramatic visual difference between *Edwin Fox* and those ships built in the late eighteenth century. The shift between 'old' and 'new' appears to be realised in the 1830s. A note on the ship, *True Briton*, built in the Blackwall Yard in 1835, describes the ship as having a 'very ugly bow, almost straight stem, foremast pitched right in the eyes, galleried stern, an ugly ship' (Figure 125) (Lubbock 1950:34). The Blackwall frigates are described as full at midships with little deadrise and a heavily modified tumblehome (Lubbock 1950:107). The early 'Blackwallers' resembled the heavy stern frames, massive quarter galleries, carved balconies and stern windows of the older East Indiaman design (Lubbock 1950:108).

The ship, *Seringapatam* (1837), was the first design to change from having double stern galleries (Figure 126) (Lubbock 1950:108). The internal structures were constructed using a mixture of Malabar teak and Sussex oak for the frames (Lubbock 1950:110). This demonstrates the constant refinement of the vessels' design for sailing the same economic routes between Britain and the eastern colonies. Costley (2014:40) argued *Edwin Fox* resembled the design of a Blackwall Frigate—a common label applied to ships built between 1837 and 1869.

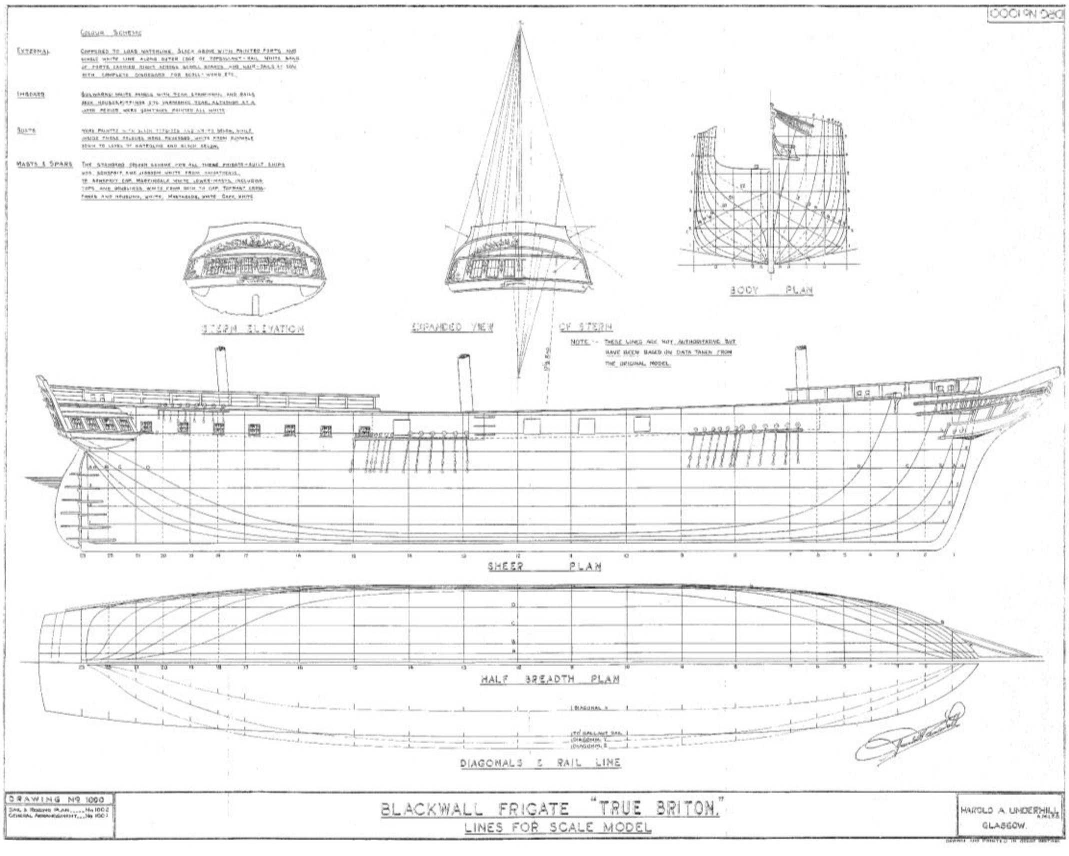

Figure 125. Ship's plan of *True Briton* reproduced for scale modelling (Harold A. Underhill, Brown, Son and Ferguson Ltd).

Figure 126. A model of *Seringapatam* (1837) ([SLR0763] © National Maritime Museum, London, Greenwich, London with permission).

Structural differences are also prevalent when assessing the data set presented previously. *Griffin*'s keel was assembled using three separate longitudinal components. The measurements presented earlier in Table 48, reflect its cross-sectional dimensions, because recording in situ was limited (Goddio and Guyot de Saint Michel 1999:60). Interestingly, the arrangement of the three components meant the rabbet was placed along the upper edge of the bottom timber (Figure 127). This was a feature that by 1796 Gabriel Snodgrass had not seen for 'many years' on East India ships, but noticed the method was still practiced in naval vessels (Snodgrass 1797b:6). With the archaeological evidence of *Endeavour*, it is clear, the keel is formed in parts using single large pieces of timber. *Endeavour*'s keel is a clear development compared to Gabriel Snodgrass's recollection of how keels in the early to mid-eighteenth century were assembled.

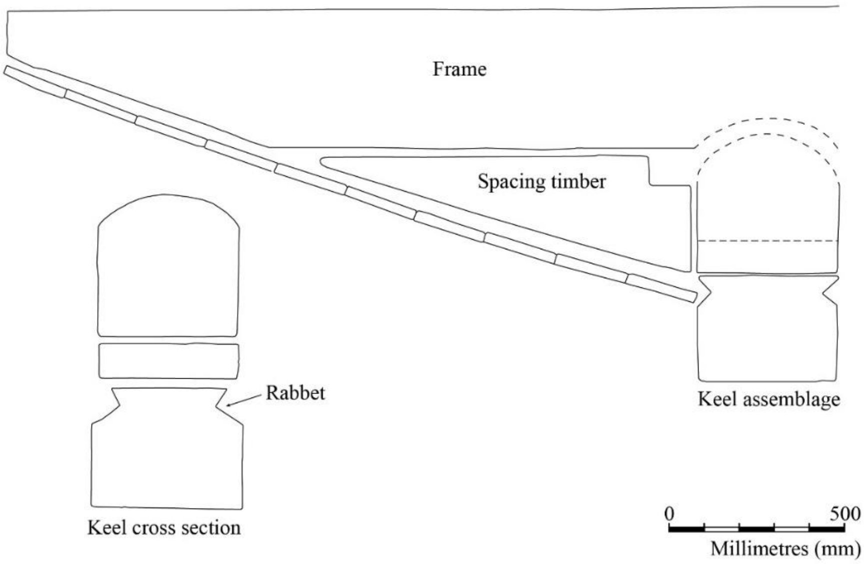

Figure 127. *Griffin*'s keel as recorded in situ (after Goddio and Guyot de Saint Michel 1999:61 and 62).

Earl of Abergavenny exhibited vertical and horizontal scarf joints along its keel with a vertical scarf joint recorded amidships (Cumming 2002). Both *Endeavour* and *Edwin Fox* recorded scarf joints, although not directly at amidships. Components of *Endeavour*'s keel were assembled with a vertical scarf, although it is not known if there was a mixture of vertical and horizontal scarf joints along its keel. Whereas *Edwin Fox* displayed only horizontal scarf joints arranged along the entire length of its keel. It is possible that by the mid-nineteenth century colonial shipbuilding techniques reverted solely to employing one form of scarf joint along a ship's keel. Furthermore, additional BEIC ship sites would contribute to understanding the exact types of joints used and the differences in dimensions.

Griffin's outer planking widths and thicknesses are smaller when compared to the other late eighteenth-century ships; however, the plank thickness became thin again in the mid nineteenth-century. This difference in sizing over time is because of milling practices and later, recommendations made by Gabriel Snodgrass. Early-eighteenth-century East Indiamen like *Griffin* reflect the timber economy of the time. Mechanical timber mills were something of a rarity in early eighteenth-century Britain and only arrived later when steam-powered mills began operating (Goddio and Guyot de Saint Michel 1999:64). As a result, manual milling practices caused the variations in the thicknesses of the timber planks used in early-eighteenth-century shipbuilding (Goddio and Guyot de Saint Michel 1999:64). By the late eighteenth century, Gabriel Snodgrass recommended that ships be planked with greater thicknesses than 76.2 mm (3 inches) as was done in the past, and this is evident on *Griffin* (Snodgrass 1797b:5). The adoption of increased planking thicknesses correlates with the registered tonnage of the ships being constructed (Figure 128). This graph illustrates the thicknesses of Company ships' planks becoming thicker towards the end of the eighteenth century. Snodgrass argued for these adaptations to increase the protection of the ships' hulls and to minimise future repair, thus reducing the Company's timber demand (Snodgrass 1797b:3–5). It was thought ships with thicker bottoms could be chartered for more voyages than their predecessors, therefore lessening the requirement to build new ships.

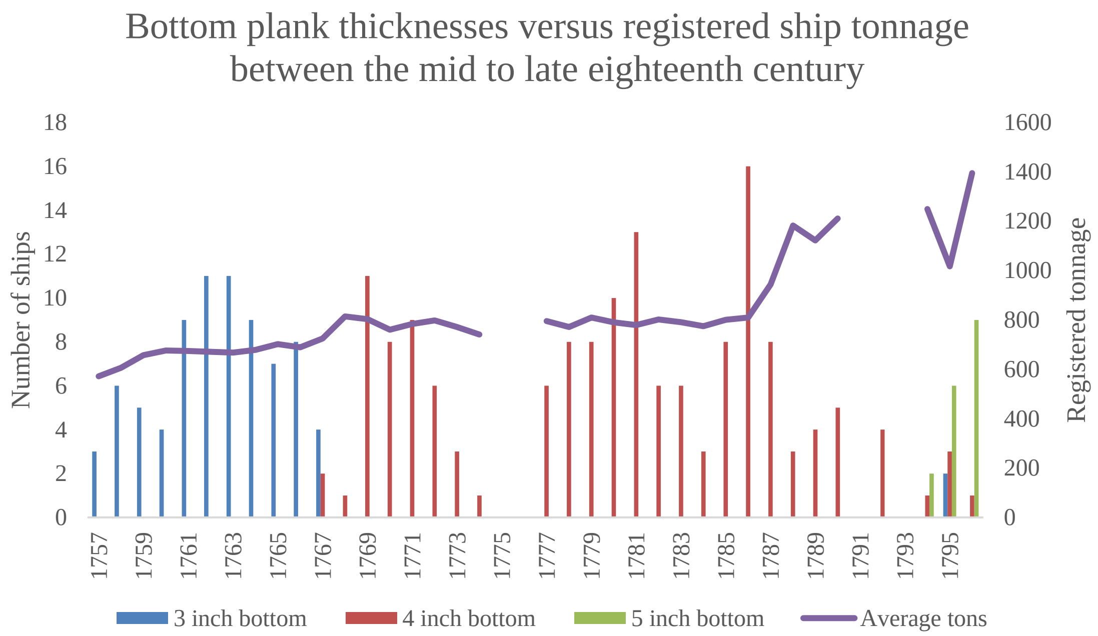

Figure 128. BEIC bottom plank thicknesses versus registered ship tonnage between the mid to late eighteenth century. Data extracted from (Snodgrass 1797a:63–74).

Edwin Fox was the only vessel with evidence of a double layer of outer hull planking—the latter fastened in an outward fanning fashion, from vertical at midships to diagonal at the bow and stern. Diagonal planking has been recorded before in other nineteenth century archaeological contexts. Gustav Milne's et al. (1998:74–75) *Nautical Archaeology on the Foreshore* presented ships that displayed two or more planking layers with cloth in between. The planks were described as thin layers and fastened to each other with copper nails and the outer planks set on diagonals. These examples are like that observed on *Edwin Fox*. In addition, Milne et al. (1998:75) note the technique was used from the early nineteenth century. The technique of diagonal layering demonstrates an early form of timber laminate and strengthening that would be indirectly adopted into late-nineteenth- and early-twentieth-century yacht development (Conrad 1998:23, 33, 110 and 150; Elliot and Kidd 2001:12–13; Madsen 2017:76).

The concept of double hull planking on British ships, however, was not exclusive to the nineteenth century. The seventeenth-century English ship, *Warwick*, excavated in 2008, revealed two layers of hull planking orientated longitudinally, with a third thin layer of timber sheathing (Bojakowski and Custer-Bojakowski 2017:291–292). Unlike *Edwin Fox*'s similar dimensions between its first and second layer, *Warwick*'s second layer of planking was thinner than the first layer, measuring between 30 to 40 mm thick (Bojakowski and Custer-Bojakowski 2017:292). The presence of the double hull planking raised questions about the vessel's age, with dendrochronology disproving the hypothesis that the ship was older and had been retired into colonial service (Bojakowski and Custer-Bojakowski 2017:301). Rather, *Warwick* was constructed with strength and quality in mind and reflects a shipbuilding technique that would continue into the nineteenth century. Other nations also practiced double hull planking (see van Duivenvoorde 2012:7; van Duivenvoorde 2015a:186–193).

In the late eighteenth century, Gabriel Snodgrass (1797b:3) recommended instead of a major repair, that the bottom and upper works of a vessel is 'doubled with three-inch oak plank, from keel to gunwale'. It was argued by Snodgrass that this would save timber over the long term while keeping ships at sea for longer periods of time. This implies that BEIC ships were constructed with one layer of outer hull planking and later received a second layer to ensure longevity of the hull. This technique became known as 'doubling' and was used throughout the nineteenth century for deficient hulls (Sexton 1991:60). It is not known if double layering of planking on BEIC ships was ever implemented in the late eighteenth century as there is currently no archaeological evidence of this. The ships, *Endeavour* and *Earl of Abergavenny*, are possible candidates, although there is currently no evidence of a double layer of hull planking. It does, however, raise questions as to when ships reverted from double planking seen in the seventeenth century to single outer planking in the eighteenth century. Importantly, *Edwin Fox* demonstrates the technique of employing double hull planking as a method of strengthening the hull, and a continuation of Snodgrass's philosophy.

The adoption of ship sheathing is influenced by inventiveness and refinement over time. From the early eighteenth century, archaeological evidence from *Griffin* shows that shipwrights used pine sheathing boards and iron filling nails, whereas by the late eighteenth century, ship sheathing consisted of copper sheets as a new antifouling technology. *Endeavour*'s copper sheets measured 1,401 mm long, compared to those of *Earl of Abergavenny* and HMS *Buffalo* which measured around 1,200 mm long. This can be compared with the use of copper sheets fastened to 'country ships' built in India during the eighteenth century. Sheets measured 35 cm by 35 cm and 1 mm thick and were fastened to the hull with 3 cm long flat head copper nails with a square 4 mm by 4 mm cross-section shank (Ball 1995:54). The nails were driven in 4.5 cm apart and the sheets overlapped by 4 cm (Ball 1995:54). Therefore, during the eighteenth century, the use of copper sheathing was still in the trial phase of adopting standardised sizing of the sheets, with the British standard eventually adopting 1,219 mm (48 inches) long by 355 mm (14 inches) wide (Bingeman 2018:11). These standardised dimensions are closest to the sheets attached to *Edwin Fox*'s hull. What remained similar over time is the sheets' overlap widths, with all three case studies recording up to 40 mm, which is also comparable with the ship *Griffin*.

Adoption to new technologies was not often accepted on first suggestion or demonstration. It was not until the 1770s that the admiralty took a 'renewed interest' in copper sheathing technology (Staniforth 1985:24). Then in the 1830s, introducing a copper alloy (Muntz metal) to market proved to be difficult at first. Merchants and shipowners were cautious to apply the new metal to their ships' hulls, especially since pure copper had been working (Staniforth 1985:27). During the early 1830s, Muntz persuaded ship owners to fix one or more sheets at a time to their vessels to prove their effectiveness (Webster 1844:116). Over time the 'new metal' was deemed satisfactory and was cheaper than pure copper—£18 cheaper per ton than pure copper sheets. Furthermore, the effectiveness of the Muntz metal was guaranteed by the manufacturing company for three years, unlike the two years guaranteed for pure copper (Webster 1844:116–117).

By the turn of the nineteenth century it is evident that copper sheathing became standardised in terms of its dimensions, the only difference being the further refinement of metallurgy and the invention of Muntz metal. What remains consistent between late-eighteenth-century copper sheets and Muntz metal is the use of non-ferrous fasteners, sheet overlap (35 mm to 40 mm) and the sheets' dimensions. Therefore, the technology took almost a century to refine into an effective standardised industrial antifouling technology.

Finally, this is the first time that previous BEIC ship studies have been combined and, when assessed with three new case studies, lays a foundation for future studies. However, past recordings have inconsistent comparative data sets. This highlights the importance of practicing consistent hull and timber recording methodologies to allow for a critical assessment of technologies and adaptive behaviours over time (see Castro et al. 2017). Thus, future BEIC ship studies should strongly consider maintaining this consistency to ensure global ship development studies are effective.

8.4 Assessing performance and behaviour

Gould (2000:72) argued that the performance of ships can be assessed through length/speed ratios. This is calculated from speed (knots) divided by the square root of the ships' hull length at the load line. In this simplified form, it is possible to determine how fast the ship was sailing compared to its size. Ships, however, are complex machines assembled with several layers of knowledge, technologies and materials. This thesis argues that speed is not the sole measure when assessing the performance of the ship. Its performance starts with understanding its structure and the development of its hull.

The British East India Company ships have been the subject of performance analysis before, with studies focussing on speed and attributing the introduction of copper sheathing to faster sailing times (Harris 1966:566). Peter Solar (2013) calculated from vessel logs that the BEIC's ship speeds fell by a third between the early 1770s and 1820s. Solar (2013) again attributed these gains to sheathing the ships' hulls with copper along with increased navigation knowledge. A recent study suggested that ship speeds increased due to improvements in ship design and technology (Kelly and Gráda 2019).

To judge a ship's performance solely on speed, however, is too narrow a focus. In the case of BEIC ships, a speedier vessel in no way implies more voyages or the transport of greater cargo volume (Harris 1966:566). For example, sailings between Britain and Asia were still dictated by the seasons. The ships would sail from the Downs between January and March in one year and then return to London in June or July the following year (Chatterton 1912:183). Economically, the BEIC ships were regulated by the Company's overarching trade monopoly, dictated by the seasons and their maximised design parameters for increased cargo carrying capacity. Even in the early nineteenth century, initial Blackwall designs were modelled on the 'old John Company' with a preference for comfort rather than speed (Lubbock 1950:111).

During the voyage, however, speed was critical for transporting the goods as quickly as possible to market. Crews would race their ships to be the first to port and to take advantage of the best market rates before supply and demand weighed in on the economics. The faster the ship, the quicker its cargo could be sold at the destination before the rest of the fleet arrived. Although, ships were dictated by seasons as to when they could depart a port, specifically, the addition of copper sheathing enabled the ships to spend less time at sea.

While historic quantitative data referring to speed can argue for reasons of improvements, archaeological investigations of individual ship technologies can reveal why these improvements occurred. To demonstrate this premise, performance characteristics of different sheathing technologies used in the eighteenth and nineteenth centuries is assessed using Michael Schiffer's performance characteristic matrix (Table 50).

Table 50. Performance characteristics for antifouling technologies.

Activity and performance characteristic	Timber sheathing	Single metal sheathing	Mixed metal sheathing
Resource and component acquisition			
Reduced cost of materials	-	-	+
Increased risk of galvanic action with iron fasteners	-	+	-
Functions			
Protection from shipworm	-	+	+
Protection from marine organism growth	-	+	+
Increase in sailing speed	-	+	+
Supports water tightness properties of hull	-	+	+
Operation, maintenance and repair			
Easily applied	-	+	+
Reduces need for repair on underlying hull timbers	+	-	+
Ability to be beached easily without damage	+	-	-
Increased voyages before replacement	-	-	+

This matrix reveals the development of ship sheathing during the late eighteenth and early nineteenth centuries. The shift from timber sheathing to copper sheathing reflects a dramatic increase in sailing performance as well as protecting the hull while at sea. The adoption of copper and copper alloy sheathing prevented marine organisms from colonising the hull and therefore reduced the drag when sailing. Although, the coppered ships reduced their voyage times by up to two months, the maximum number of voyages remained the same (Harris 1966:566). Regardless, the economic benefit from the introduction of copper sheathing meant saving costs while afloat, longer life and reduced maintenance (Harris 1966:566). The move from timber sheathing also reduced the overall weight of the ship. Standardised weights of sheathing sheets developed in the early nineteenth century controlled the total weight on the hull while performing efficiently. Thus, through the individual analysis of a technology, we can now understand how invention, adoption and refinement of ship technologies and materials contributed to a vessel’s development and performance over time.

8.4.1 Ship development model

In the past, notions of evolutionary analogies have been used to explain watercraft development and indicate their linear progression between descendant and antecedent types (Adams 2013:50) To assess ship development without a biological correlation, an S-curve model based on the results discussed in this chapter are encapsulated here (Figure 129). The traditional shape of the S-curve has been split into three segments with the centre S-curve inverted. This subsequently, removes the notion that ship development follows any linear evolutionary models. The three individual S-curves represent how developments can occur separately from each other in time and space. The centre line models the developments stagnating in time where there has been no revolutionary introduction or adoption of technology; rather, this period represents a stage of refinement.

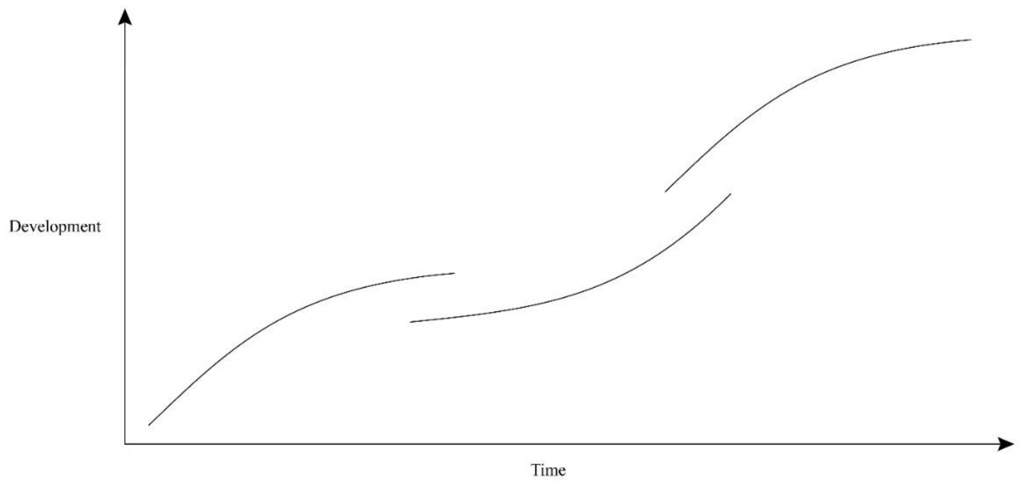

Figure 129. S-curve ship development model.

When considering the three case studies explored in this thesis, the S-curve model demonstrates their development over time. For example, *Endeavour* is included in the progression of the first line. This illustrates there was greater development during the vessel's construction. The use of copper sheathing is seen as a major development for ship protection and speed. HMS *Buffalo* fits the middle line whereby limited development is observed. The hull shape continued with previous design parameters and incorporated sheathing technology that was used in the previous century. Little refinements, however, such as new pitch compounds reflect the gradual upward progression of development as a whole. Finally, *Edwin Fox* is represented by the third line and reflects the latter half of the curve whereby the vessel incorporates new and refined technologies introduced in the 1830s. For example, *Edwin Fox* was sheathed in Muntz metal and the adopted hull design moved quicker through the water.

By having multiple S-curves it allows for geographically spaced ideas, knowledge and technologies to be included in understanding how BEIC ships have developed and overlapped during the late-eighteenth to mid nineteenth centuries. The overlap of the curves also demonstrates that inventive and adopted ideas can occur at the same time in different locations. Individually, the curves themselves represent their own shipbuilding microcosm of inventive, adoption and refinement processes. Overall, the general trend of development is continually improved over time, whilst acknowledging that shipbuilding cultures can develop and manufacture technologies without ever contacting each other.

8.4.2 Summary

In the past, performance analysis of BEIC ships have been demonstrated by measuring their speed based on historical data, whereas this research specifically investigates individual ship components and technologies to demonstrate how subtle differences contribute to the overall development and improvement of these vessels. This further confirms and complements previous studies when assessing speed, while contributing significant cultural insights. The inclusion of the S-curve model represents the combination of different assembled technologies and demonstrates ship development over time. The use of several S-curves acknowledges how these complex machines were developed simultaneously with or without cross-cultural contact.

8.5 Insights into shipwright behaviours

Through the archaeological investigation of *Endeavour*, HMS *Buffalo* and *Edwin Fox*, valuable insights into shipwright behaviours are observed. Shipwright attitudes reflect the changing environment surrounding them, including social, political, economic and environmental factors. This in turn, influenced the shipwright’s ability to carry out tasks within the yard. What is observed is a transfer and diffusion of knowledge across geographic regions and over time. When looking at the three primary case studies, technologies and materials were invented, adopted and refined over time with a criss-crossing of knowledge between the United Kingdom and British-held colonies.

Socially, shipyards, when under the control of the British East India Company, were organised under departmental heads. The ‘Clarke of the Yard’ supervised the shipwrights as they worked (Chatterton 1912:82). The Clarke’s role also included supervising cawlkers [caulkers], carpenters and labourers. The Master shipwright was responsible for building and repairing the Company’s ships and was forbidden to construct ships for anyone else (Chatterton 1912:82). By the early eighteenth century, however, the company moved to tender ships to private individuals and shipyards. This relaxing of Company-controlled shipyards opened the doors for individual shipwrights to work with greater individual licence than when they were directly supervised by Company supervisors.

Control in the shipbuilding process was still maintained as the ship’s husband was a person employed as the link between the Company and the ships it tendered. They were private individuals who were given the right to build ships, which the Company was obligated to charter at stipulated rates (Cotton 1949:48). These chartered tonnages was generally set at 499 tons between 1748 and 1772 (Cotton 1949:49). The husband attended meetings by the Court to listen to voyage plans and to learn the requirements of shipping (Chatterton 1912:81). The husband was also responsible for supervising the clerks and keeping accounts and stores in London (Chatterton 1912:81).

While there was top down control at an administrative level, the shipwright held full control on how to assemble the ship. The shipwrights retained full artistic licence to construct the vessels how they knew, provided they met the company’s specifications. Their craft, however, was still under supervision by the ship’s husband, who directed to what size the ship needed to be built by the Company’s tender process. Therefore, *Endeavour* and HMS *Buffalo* reflect the overall Company’s dimensions specific in the tender process, while the individual components reflect the shipwrights and labour processes employed in the yards.

Politically, the ships were a connection between control and wealth and the BEIC moved to maintain this control where it could. The political environment at the end of the eighteenth century arranged political alliances to secure shipping for the future. Unions of shipbuilders on the River Thames convened to counter any competition. They agreed ‘not to build a ship for any person who would tender her [it] to the Company at reduced freight’ (Mehta c.1923:11). In addition, a more audacious move was implemented to buy up India stock and to acquire votes as proprietors in the colony (Mehta c.1923:11). This meant shipowners had substantial voting power when it came to the Company’s decision around its ships. Furthermore, they maintained their monopoly of building the ships to serve the East India trade (Davis 1962:70).
In 1772 the Company was allowed to build or hire ships constructed in India that were intended for local trade and defence (Cotton 1949:45). The Company’s directors were opposed to any use of Indian built vessels for the main trading routes between the East and Britain. This attitude changed, however, with the introduction of *The Charter Act 1793*, which required the company to provide 3,000 tons of shipping for local trade (Cotton 1949:45). Additional pressure was mounting for the Company’s ships as some were pulled into service by the British Government in the war against France (Cotton 1949:45). To make up for the deficit in tonnage, in June 1795, the Company was authorised to use ‘proper ships’ built in its territories ‘to bring home their investments of goods from China and India, in spite of the English Navigation Law’ (Cotton 1949:45). It was after this time that Indian-built vessels became regular in the Company’s chartered fleet.

Shipwrights were politically driven, both from the Company securing their monopoly as well as the shipwrights securing their own domestic industry. In the 1790s, ‘Extra company ships’ were contracted to deliver cargo to Britain. The presence of India-built ships on the River Thames drew both criticism and praise. Criticism came from local shipowners and shipwrights who became concerned for their own local industry (Bulley 2000:15). With the threat of opening the shipbuilding industry in Britain’s colonies, the shipwrights moved to block such an outcome. This effectively helped to secure their industry, livelihoods and legacy of domestic shipbuilding knowledge. This control is seen with similar scantlings between *Endeavour* and HMS *Buffalo*. As time went on, however, this dominant union could not retain control. In some ways, the global shift of the industry contributed to design standards, such as the incorporation of the 'Bengali straight-sided vessels' that Snodgrass had observed and advocated for, and as seen in HMS *Buffalo* and *Edwin Fox*. As a result, by the shipwrights being forced to adopt foreign shipbuilding techniques and technologies, they themselves and the nation of Britain ultimately benefited from learning and refining ship design and construction.

It is not conclusive if shipwrights were influenced by the environment directly. The three case studies presented here show many of the scantlings remain consistent across time. Furthermore, highly industrialised technologies like copper sheathing continued as standardised form and function. It is likely that shipwrights continued with prior knowledge and learnings acquired through apprenticeships regardless of where they practiced the art of shipbuilding. The adoption of mechanical manufacture makes it difficult to distinguish personal signatures on the materials; rather it reflects an industrialised society. What is conclusive, is that shipwrights quickly adapted to working with foreign timbers for shipbuilding components. It is likely that knowledge working with such timbers was transferred between foreign groups and with new information diffusing among more localised shipbuilding communities. The conversion of the timbers recorded in the three case studies shows similar approaches to milling and for the placement of those timbers within a ship's hull. The process of converting and working the timber remained consistent over time or with the introduction of different woods. The shipwrights themselves retained their trained knowledge and continued to apply that to new materials rather than the materials influencing a change in skill. Finally, only with the gradual acceptance of opening the domestic shipbuilding industry to include foreign skills and ideas, BEIC ships began a new era of innovation, adoption and refinement.

8.6 Summary

The three vessels, *Endeavour*, HMS *Buffalo* and *Edwin Fox* reveal similarities and differences in colonial ship development. During the late-eighteenth century to the mid-nineteenth century, design parameters and timber dimensions remain consistent. It is with the introduction of new technologies, such as metal sheathing, that overall performance of a vessel increased. These vessels developed and improved in performance characteristics through the introduction of technologies and the adoption of foreign shipbuilding knowledge. British shipwrights were a powerful union during the latter part of the eighteenth century and this was detrimental to advancing adoption of new technologies and materials. As a result, innovative development stagnated around the beginning of the nineteenth century for a short time. What is evident after assessing the three case studies, however, is that shipbuilding knowledge transferred and diffused geographically, although sometimes reluctantly, for the improvement of ship manufacture.

Chapter 9. Conclusions

> The study of technical detail in shipbuilding is not at all parochial, but provides us with an exceptional opportunity to understand past thinking, concepts and decisions (Maarleveld 1995:4).

Fifty-eight years ago, Ralph Davis (1962:74) hoped that ‘nautical archaeologists will one day investigate’ change in English shipbuilding that led to improved efficiencies. This thesis specifically investigated design and technological developments in British merchant vessels used in the East India trade that ultimately led to improved hull performance. In order to understand these changes, this nautical archaeological study examined the conception phase, the sharing of cross-temporal knowledge, the innovation and adaptation to design ideas, materials and technologies used for constructing *Endeavour*, HMS *Buffalo* and *Edwin Fox*.

This thesis set out to address six research aims.

1. To identify external factors affecting information exchange between shipbuilding industries, including, economic, political, social and environmental factors.

This study combined the historical record and the archaeological record to identify external factors affecting information exchange. Economic, political, social and environmental factors that influenced the shipbuilding industry are documented in archival sources, whereas the archaeological record demonstrates how shipwrights were adapting to new design parameters and construction technologies. Individual ship components, when studied in detail, reveal valuable insights into external factors that influenced change within the British colonial shipbuilding industry.

2. To use material evidence to produce quantitative data to interpret design and construction changes over time.

This research recorded vessel dimensions from historic ships’ plans and a preserved historic hull to calculate design parameters. This assisted in comparing changes in hull shape over time. Additionally, ship timber components were investigated individually, revealing comparable diagnostic construction traits and dimensions. Together, they supported this study to explore the similarities and differences between the three case studies over time. Furthermore, a quantitative approach contributed to analysing the technologies employed on these vessels in more precise detail.

3. To determine how existing knowledge was applied to new timber resources by shipwrights and to consider how local timber resources influenced the way shipwrights of British shipyards in India constructed vessels.

British shipwrights retained their shipbuilding techniques regardless of their adoption of new timber resources. The adoption of milling technologies showed how timbers were converted from the parent tree while their dimensions remained consistent, irrespective of the introduction of new wood types. British shipbuilding knowledge was applied to domestic and foreign timbers and remained consistent over time.

4. To determine how innovation and adaptation to new technologies contributed to the advancement of ship design.

The British shipbuilding industry progressed by employing innovative technologies and by adapting existing technologies. Adopting foreign shipbuilding design elements with domestic inventions of new technologies helped to improve the ships' designs. These advancements contributed to the vessels having longer sailing careers through improved seaworthiness and reduced costs of resources.

5. To develop a framework to understand ship development and to contribute to nautical archaeological studies.

An S-curve model was produced using the results collected for this thesis. The traditional S-curve model is reconfigured to represent three individual S-curves. Thereby, the model represents the three primary case studies at different points of development, reflects the ongoing innovation and adaptations in the British shipbuilding industry and acknowledges that similar stages of development can occur across multiple geographic regions. The S-curve model is also applicable to future ship development studies.

6. To confirm the historical record of *Endeavour* and to undertake the first comprehensive recording of *Endeavour*'s ship timbers.

The inclusion of *Endeavour* in this research was the first time the ship's timbers have been recorded in detail. Discrepancies found during the initial review of published literature indicated misleading descriptions about the vessel and its dimensions. Extensive archival research retraced the vessel's construction, voyages and a major repair. The historical documents also confirmed the ship's original construction date. Combined with the detailed recording of the ship's timbers, new insights formulated from this research are made available to local heritage management and the wider public.

These aims contribute to answering the primary research questions: 'How does the cultural transmission of design and construction practices of British East India Company ships contribute to our understanding of ship manufacture during the eighteenth and nineteenth centuries; and to what extent did social, political, economic, cultural and environmental factors influence ship development and the exchange of information between shipwrights?' Together, historical research, hull design calculations, ship timber recording, material analysis and dendrochronology inform us of how vessel development occurred through time and space. Furthermore, it reveals how shipwrights were adapting, managing, innovating and refining the art of shipbuilding. Using this study's detailed analysis, the performance characteristics concerning antifouling technology are assessed, demonstrating its contribution to ship development. Finally, this research advanced an S-curve model to reflect the development of *Endeavour*, HMS *Buffalo* and *Edwin Fox*, while allowing for geographic variability and the criss-crossing of knowledge and technologies. It acknowledges that ships can develop simultaneously and similarly, directed by groups of artisans. British vessel manufacture benefited from cross-cultural contact and the observation and sharing of design and construction ideas and technologies. Finally, major developments and refinement are observed over an approximate 80-year period of innovation and adoption.

9.1 Limitations

Museum ship timber collections should be approached with caution. The timbers recorded for this research were received by the museums over several decades. As a result, provenance and contextual information relating to the timbers was limited. This missing information made it difficult to accurately identify where the timbers belonged in the ship structure. Therefore, comparative assessment of similar timbers between the case studies was complex.

Preserved historic hulls make recording individual timber components in detail difficult. This is because ship components are still fastened together, prohibiting accessibility for the researcher to conduct their work. In the case of *Edwin Fox,* the museum prohibits the removal of components as this would affect the integrity of the hull as well as potential aesthetics for visiting museum patrons. Therefore, some measurements and identification of features and components could not be recorded for this study.

Dendrochronological ship studies face limitations due to the varying dimensions of individual ship components. Cross-dating requires a minimum of 50 tree rings for a statistical match with master chronologies. As found with the coring of *Edwin Fox*, only large timber components (i.e. keel, keelson, floors) produced more than 50 rings for measuring. Smaller timbers, like planking, yielded a smaller count of tree rings. Furthermore, the preserved hull of *Edwin Fox* reduced accessibility for coring. Some angles required for coring were unobtainable due to the completeness of the hull. Therefore, the coring of the *Edwin Fox* hull was limited to the larger timber components and directed by coring accessibility.

9.2 Future research

The historical research conducted for this study revealed descriptions about female shipwrights employed in dockyards. As early as the sixteenth century, Margaret Glinster (or Glirister) is listed as a Master Shipwright (Dyer 1926:451). In the late eighteenth century Mary Slade (nee Lacy) apprenticed as a ship's carpenter on *Royal William* before working as a shipwright in the Portsmouth Dockyard (Corney

1920:350). Mary Slade (1773) wrote a memoir detailing her life and time working as a shipwright. This thesis acknowledges that these workplaces were of mixed gender, although with the recorded histories dominated by male shipwrights. Future archaeological investigations should develop methods for identifying gendered signatures within ship structures and examine how mixed gendered roles in the shipbuilding yards contributed to ship development (see Cullon 2003).

The data collected for this research has the potential to be comparable with other British merchant ship sites investigated in the future. If similar ship sites are investigated with the same level of detail, our understanding about how these ships developed with the introduction of technologies and resources will be significantly increased. A detailed database using this expanded dataset will significantly benefit future nautical archaeologists and the wider scientific community.

Future investigations have the potential to investigate the provenance of metal elements. It is difficult, however, to accurately pursue this with non-ferrous alloys, such as Muntz metal, whereas pure copper applied to ships prior to c.1830 allows the possibility to contribute to understanding where raw materials originated. This unlocks new avenues of research to explore how the British shipbuilding industry was sourcing and securing raw materials for the benefit of its ships.

It is recommended that a full survey of the *Edwin Fox* hull be completed as soon as possible, with each component receiving a unique identifying number. This will aid future researchers to investigate its hull components, and ensures that a standardised approach to nautical studies is consistently applied. This will also keep records of the timbers' conditions and can be used for future conservation and site management roles.

Detailed site surveys of the *Endeavour* and HMS *Buffalo* shipwrecks should be completed at the earliest opportunity and be continually revisited to assess any changes. This will provide museums with an up to date record to offer information for provenancing their own collections. An accurate site record will also contribute to ongoing site management and heritage promotion for local jurisdictions and communities.

For broader studies, research questions should continue to focus on investigating responses to European colonisation through shipbuilding techniques and industry. Potential archaeological sites could include ship sites, shipbuilding yards, milling yards and areas of raw resources procurement. Trade networks can then be analysed focussing on connectivity between people, place and resources. Cultural landscapes can also reveal insights into how the shipbuilding industries, both foreign and domestic, were shaped by their surrounding environments.

Finally, this study is the first to combine previous British archaeological investigations with three new case studies and by doing so, sets the foundation for a growing data set. In the future, such a database offers insightful trends and traits that will enhance our knowledge about these ships. With data reflecting form and function and technologies, research questions can delve more broadly into the holistic realms of the ships themselves and the societies that created them. This is significant for understanding British shipbuilding culture, both foreign and domestic, and the influences obtained through interactions with other shipbuilding artisan groups.

9.3 Significance

This research is significant because it is the first time British East Indiamen and colonial merchant ship materials have been analysed together to understand the transfer of shipbuilding knowledge with changes in design and construction technologies. The methodologies employed for this study are applicable to future investigations of similar sites. Additionally, the ships' timber catalogue is a revised version from previous nautical archaeological studies and demonstrates its value for future research opportunities. Furthermore, the framework applied to this thesis is applicable to other global ship studies in relation to the examination of technological transfer and performance.

The three primary case studies highlight Aotearoa New Zealand's rich nautical archaeological and maritime historic record while contributing to the existing dataset of British colonial merchant vessels. Until this study, *Endeavour*, HMS *Buffalo* and *Edwin Fox* were known locally with their historical global connections promoted through published resources and by their respective museums. This investigation builds upon this historical narrative by highlighting the significant archaeological and scientific contribution these ships provide to understanding the development of watercraft.

9.4 Conclusions

Finally, ships are some of the most complex machines created in the past and only through the detailed analysis of ship design, individual structural ship components and associated materials can we reveal valuable insights into BEIC vessel development. This thesis contributes to the understanding of British colonial merchant ship development between the late eighteenth and mid-nineteenth centuries. The primary case studies selected for this study serve as ‘a link in the chain of progression in the art of ship building—a ship that when built was considered a triumph of skill, a credit alike to designer and builder’ (Barnett 1991:62).

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Glossary

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Adze. An axe-like tool with its blade at right angles to the handle, used for shaping and dressing wood (Steffy 1994:266).

Amidships. The middle of a vessel, either longitudinally or transversely (Steffy 1994:266).

Athwartships. Across the ship from side to side; perpendicular to the keel (Steffy 1994:267).

Back rabbet. The upper surface of a keel rabbet or the nesting surface of a post rabbet (Steffy 1994:267).

Back rabbet line. The line formed by the junction of the inner plank surface and the upper, or inner, rabbet surface (Steffy 1994:267).

Ballast. Heavy material, such as iron, lead, or stone, placed low in the hold to lower the center of gravity and improve stability (Steffy 1994:267).

Beam. A timber mounted athwartships *to* support decks and provide lateral strength; large beams were sometimes called *baulks.* See also **Breadth** (Steffy 1994:267).

Beveled edge. *See* **Chamfer** (Steffy 1994:267).

Bilge. The area of the hull's bottom on which it would rest if grounded; generally, the outer end of the floor. When used in the plural, especially in contemporary documents, **bilges** refers to the various cavities between the frames in the floor of the hold where bilge water tends to collect (Steffy 1994:267).

Bilge keel. A secondary keel placed beneath the bilge or at the outer end of the floor. Sometimes called a **sister keel** (Steffy 1994:267).

Bolt. A cylindrical metal pin used to fasten ships' timbers together.

Bottom. The underwater portion of a fully loaded hull; also used as a general designation for a seagoing vessel (Steffy 1994:268).

Bow. The forward part of a hull, specifically, from the point where the sides curve inward to the stem (Steffy 1994:268).

Bowsprit. A spar projecting forward from the bow (Steffy 1994:268).

Breadth. The width of a hull; sometimes called **beam**, which is technically the length of the main beam (Steffy 1994:268).

Breast hook. A large, horizontal knee fixed to the sides and stem to reinforce and hold them together (Steffy 1994:268).

Butt. The lateral end of a hull plank or timber (Steffy 1994:268).

Butt joint. The placement of two planks or timbers whose ends were cut perpendicularly to their lengths; sometimes called carvel joint (Steffy 1994:268).

Buttock. The convex part of the hull beneath the stern deck (Steffy 1994:268).

Buttock lines. Projections on a lines drawing that reveal vertically oriented longitudinal hull shapes (Steffy 1994:268).

Careen. To deliberately list a vessel so that part of its bottom was exposed for caulking, cleaning, repairing, etc (Steffy 1994:268).

Caulk [Calk]**.** To drive oakum, moss, animal hair, or other fibrous material into the seams of planking and cover it with pitch to make the seams watertight (Steffy 1994:268).

Ceiling. The internal planking of a vessel (Steffy 1994:269).

Chamfer [Beveled edge]**.** The flat, sloping surface created by slicing the edge off a timber (Steffy 1994:269).

Chock. An angular block or wedge used to fill out areas between timbers or to separate them; chocks were used to fill out deadwoods and head knees, separate frames and futtocks, etc (Steffy 1994:269).

Clamp. A thick ceiling strake used to provide longitudinal strength or support deck beams; clamps were often located directly opposite the wales and acted as internal wales; a clamp that supported a deck beam was called a *shelf clamp* (Steffy 1994:269).

Clench [Clinch]**.** To secure a nail or bolt by bending or flattening its projecting end over the surface it last penetrated; a nail whose tip and shaft were both clenched is said to be double-clenched, as in the fastening of ancient ship frames and planks (Steffy 1994:269).

Coaming [Combing]**.** A raised border at the edge of a hatch whose function was to prevent water from entering the space below (Steffy 1994:269).

Copper-bottomed [Coppered]**.** A vessel whose bottom was sheathed in copper to prevent fouling and worm infestation (Steffy 1994:269).

Copper fastened. A vessel whose fastenings were made of copper (Steffy 1994:269).

Cordage. A general term for ropes and cables (Steffy 1994:269).

Crow [Crow bar]**.** A strong iron bar, pointed or chisel-shaped at one end, used for prying or moving heavy timbers (Steffy 1994:270).

Deadrise. The amount of elevation, or rising, of the floor above the horizontal plane; the difference between the height of the bilge and the height of the keel rabbet (Steffy 1994:270).

Deadwood. Blocks of timber assembled on top of the keel, usually in the ends of the hull, to fill out the narrow parts of a vessel's body. See also **Rising wood** (Steffy 1994:270).

Deck beam. *See* **Beam** (Steffy 1994:270).

Depth of hold. The distance between either the bottom of the main deck or the bottom of its beams and the limber boards, measured at the midship frame (Steffy 1994:270).

Diagonal framing. Frames or riders placed diagonally over the regular frames or ceiling to provide additional stiffening to a hull (Steffy 1994:270).

Diagonals. Lines on a hull drawing representing specific oblique sections of the hull (Steffy 1994:270).

Dowel [Dowel pin]**.** A cylindrical piece of wood (of constant diameter) used to align two me · hers by being sunk into each. A cylindrical coak. U like treenails and pegs, dowels served an alignment function only, additional fastenings being necessary to prevent separation of the joint (Steffy 1994:270).

Draft [Draught]**.** The depth to which a hull is immersed; also, a drawing or plan (Steffy 1994:270).

Drift bolt. A cylindrical bolt, headed on one end slightly larger in diameter than the hole into is driven (Steffy 1994:270).

Fair curve [Fair line] [Faired]**.** A shape or line whose curvature agrees with the mold loft or that is mechanically acceptable and seaworthy (Steffy 1994:271).

False keel [Shoe]**.** A plank, timber, or timbers attached to the bottom of the keel to protect it in the event of grounding or hauling; on large ships, false keels were sometimes made quite thick in order to increase the size and strength of the keel. In

North America from eighteenth century onward, and perhaps in other areas, false keels were called **shoes** (Steffy 1994:271).

False keelson. *See* **Rider keelson** (Steffy 1994:271).

Flat scarf. The union of two planks or timbers whose diagonal ends were nibbed (cut off) perpendicular to their lengths. When planking is scarfed vertically, the ends are not nibbed (Steffy 1994:271).

Floor. The bottom of a *vessel* between the upward turns of its bilges (Steffy 1994:271).

Floor timber. A frame timber that crossed the keel and spanned the bottom; the *central* piece of a compound frame (Steffy 1994:271).

Flush deck. A deck running continuously from bow to stern, without breaks or raised elements (Steffy 1994:271).

Foot wale [Footwaleing]**.** Thick longitudinal strakes of ceiling located at or near the floor head line or turn of the bilge. Some eighteenth-century English documents called the thick strakes next to the limber strake, or sometimes all of the ceiling. Footwaleing in which case the heavy strakes near the turn of the bilge were known as **thick stuff** (Steffy 1994:271).

Forecastle. Variously, a short, raised foredeck, the for ward part of the upper deck between the foremast and the stem, or the quarters below the foredeck (Steffy 1994:271).

Frame. A transverse timber, or line or assembly of timbers, that described the body shape of a vessel and to which the planking and ceiling were fastened. Frames were sometimes called **timbers** or, ribs (Steffy 1994:271).

Futtock. A frame timber other than a floor timber, half-frame, or top timber; one of the middle pieces of a frame (Steffy 1994:272).

Futtock plank. In English shipbuilding, the first ceiling plank next to the limber strake (Steffy 1994:272).

Garboard strake [Garboard]**.** The strake of planking next to the keel; the lowest plank. Also, the lowest side strake of a flat-bottomed hull (Steffy 1994:272).

Graving [Breaming]**.** The practice of cleaning a hull's bottom by burning barnacles, grass, and other foul material preparatory to recoating it with tar, sulphur, etc. The vessel was careened or drydocked to perform this task (Steffy 1994:272).

Graving piece. A wooden patch, or insert, let into a damaged or rotted plank (Steffy 1994:272).

Gudgeon. A metal bracket attached to the sternpost into which a rudder **pintle** was hung; the female part of a rudder hinge (Steffy 1994:272).

Hatch [Hatchway]**.** A rectangular opening a vessel's deck (Steffy 1994:272).

Hatch coaming. *See* **Coaming** (Steffy 1994:272).

Hog [Hogging]**.** The strain on a hull that causes its ends to droop (Steffy 1994:273).

Hold. In a general sense, the interior of a hull. The term is more commonly used to describe the part of a merchant ship's interior where the cargo and ballast were stowed or, on a warship, the room below the deck where stores and ballast were kept (Steffy 1994:273).

Keel. The main longitudinal timber of most hulls, upon which the frames, deadwood, and ends of the hull were mounted to the backbone of the hull (Steffy 1994:273).

Keelson. An internal longitudinal timber or line of timbers mounted atop the frames along the centreline of the keel, that provided additional longitudinal strength to the bottom of the hull; an internal keel. Most commonly, a single keelson was installed that was no larger than the keel. On very large vessels, however, various combinations of as many as a dozen keelsons were assembled. Where extra moulding was required, one or more additional keelsons, called **rider keelsons** or **false keelsons**, were bolted to the top of the main keelson. They could be of identical size to, or smaller than, the main keelson. Auxiliary keelsons bolted to along-side the main keelson were known as sister, (U.S.), side, auxiliary, or assistant keelsons. However, care should be exercised in interpreting the various keelsons from contracts. For instance, some nineteenth-century American contracts for large schooners refer to the keelson above the main keelson as the sister, and the one above that as the assistant sister keelson. On occasion, large square timbers were placed at the floor head line or near the bilge, usually above the bilge keels. These were called **bilge keelsons** or, in some British document, **sister keelson**s. Secondary keelsons did not necessarily run the full length of the hull terminating at the ends of the hold, the last square frames, or some other appropriate location (Steffy 1994:274).

Keel staple [Keel clamp]**.** A large metal staple used to attach the false keel to the keel (Steffy 1994:274).

Knee [Knee timber]**.** An angular piece of timber used to reinforce the junction of two surfaces of different planes; usually made from the crotch of a tree where two large branches intersected, or where a branch or root joined the trunk. See also **Dagger knee, Hanging knee, Lodging knee, Lodging knee,** and **Standing knee.**

Limber boards. Ceiling planks next to the keelson which could be removed to clean the limbers; on some ancient vessels, limber boards were laid transversely above the centreline of the keel. Holes or slots were sometimes cut into limber boards so that they could be lifted more easily (Steffy 1994:274).

Limber holes [Watercourses]**.** Apertures cut in the bottom surfaces of frames over, or on either side of, the keel to allow water to drain into the pump well (Steffy 1994:274).

Limber ledges. Rabbeted timbers running parallel to the keel and atop the floor timbers for the purpose of supporting transverse ceiling planks (Steffy 1994:274).

Limbers. Watercourses or channels alongside or central to the keel or keelson, through which water could drain into the pump well (Steffy 1994:274).

Limber strake. The lowest permanent ceiling strake, fastened to the tops of the frames nest to the limber boards and keelson (Steffy 1994:274).

Lines. The various shapes of a hull; expressed graphically, a set of geometric projections, usually arranged in three views, that illustrates the shape of a vessel's hull (Steffy 1994:274).

Longitudinal. See **Stringer** (Steffy 1994:275).

Mast step. A mortise cut into the top of a keelson or large floor timber, or a mortised wooden block or assembly of blocks mounted on the floor timbers or keelson, into which the tenoned heel of a mast was seated (Steffy 1994:275).

Midship [Midships]**.** A contraction of **amidships** and consequently, in a general sense, it refers to the middle of the ship. In construction, however, it is often used as an adjective referring to the broadest part of the hull, wherever that might be (Steffy 1994:275).

Midship beam. The longest beam in a vessel, located at or near the **midship bend** (Steffy 1994:275).

Moulded [Moulded dimension]**.** The various dimensions of timbers as seen from the sheer and body views of construction plans; the dimensions determined by the moulds. Thus, the vertical surfaces (the sides) of keels, the fore-and-aft sides of the posts, the vertical or athwartships surfaces of frames, etc. Normally, timbers are expressed in sided and moulded dimensions, while planks and wales are listed in thicknesses and widths. Moulded and sided dimensions are used because of the changing orientation of timbers, such as frames, where “thick” and “wide” or “height” and “depth” become confusing (Steffy 1994:275–276).

Mortise. A cavity cut into a timber to receive a tenon. Large mortises were sometimes referred to as steps (Steffy 1994:276).

Mortise-and-tenon joint. A joining of planks or timbers by which a projecting piece (tenon) was fitted into one or more cavities (mortises) of corresponding size (Steffy 1994:276).

Fixed tenon and single mortise. A tenon was shaped from the end on one timber and inserted into the mortise of the other. When the tenon of a large vertical timber was left unlocked, as in masts, and sternposts, it was said to be stepped (Steffy 1994:276).

On the bottom [Hereditary bottom]. Describes building a new ship in replacement of the one that has worn out without the Company increasing its total ship tonnage.

Orlop deck. The lowest deck of a large ship (Steffy 1994:276).

Pay. To coat; to cover a hull bottom with a protective layer of pitch, resin, sulphur, etc (Steffy 1994:276).

Peg [Tenon peg]. A tapered wooden pin driven into a pre-drilled hole to fasten two members or lock a joint. Pegs came in a variety of sizes and tapers; they could have square, round, or multi-sided cross-sections. The important difference between dowels and pegs in ancient construction was that the former were of constant diameter and lightly set, while the latter were tapered and driven with appreciable force. The most common use of pegs in ancient construction was the locking of mortise-and-tenon joints (Steffy 1994:277).

Pitch [Tar]**.** A dark, sticky substance used in caulking seams or spread over the inner or outer surfaces of hulls as waterproofing and protection against some forms of marine life. Pitches were variously derived from the resins of certain evergreen trees; from bitumens, such as mineral pitches; or from the distillation of coal tar, wood tar, etc (Steffy 1994:277).

Planking. The outer lining, or shell, of a hull (Steffy 1994:277).

Planking strake [Strake, Streake]**.** A continuous line of planks, usually running from bow to stern; the sum of a row of planks (Steffy 1994:277).

Plug treenail. A piece of straight-grained wood through which metal fastenings were driven. In some cases, pilot holes are said to have been pre-bored through their lengths. They were not driven into the holes of the planks, but fit rather loosely and expanded tightly when the nails were driven through them. Plug treenails were commonly used on the exterior hull surfaces of ancient ships to prevent leakage and splitting of the planks around the fastenings (Steffy 1994:277).

Poop [Poopdeck]**.** The highest and aftermost deck of a ship (Steffy 1994:277).

Port [Port side, Larboard]**.** The left side of a vessel when facing forward (Steffy 1994:277).

Quarterdeck. The after part of the upper deck, from the mainmast to the poop (Steffy 1994:277).

Rabbet. A groove or cut made in a piece of timber in such a way that the edges of another piece could be fit into it to make a tight joint. Generally, the term refers to the grooves cut into the sides of the keel, stem, and sternpost, into which the garboards and hooding ends of the outer planking were seated (Steffy 1994:277).

Ragging. The process of creating barbs or indents by obliquely striking the shank of a nail or bolt with a sharp tool (McCarthy 2005:179).

Rake. The inclination of the stem and sternpost beyond the ends of the keel; also, the inclination of the masts from the perpendicular (Steffy 1994:277).

Rider keelson. An additional keelson, or one of several additional keelsons, bolted to the top of the main keelson of a large ship. In some documents, it was called a **False keelson.** *See also* **Keelson** (Steffy 1994:278).

Room and space. The distance from a molded edge of one frame to the corresponding point on an adjoining frame, usually measured at or near the keelson. The part occupied by the frame is called the *room*, while the unoccupied distance between it and the adjacent frame is called the *space*. On large ships of the last few centuries, where filling frames were placed between double frames, the term applied to the distance between the molded edge of one double frame to the corresponding point on the next double frame. Because of the uneven Siding of forward frame faces, irregular spacing, and varying methods of fabrication, **room and space** is often a meaningless term in ancient hull documentation. A more definitive designation for ancient ships is **average frame spacing**, the average of distances between frame centerlines at a common appropriate location, taken throughout the hull or hold (Steffy 1994:278).

Rudder. A timber, or assembly of timbers, that could be rotated about an axis to control the direction of a vessel underway. Until the middle of the medieval period, the practice was to mount rudders on one or both stern quarters; these were known as *quarter rudders*. By the late medieval period, however, it appears that most vessels of appreciable size were steered by a single rudder hung at the sternpost; these were known as *stern-hung rudders*. For a brief period, the two types were sometimes used in combination. Rudders were designed for the vessel and type of duty they (p. 1144) served. In protected waters they could be made quite broad, while seagoing ships utilized longer, more narrow rudders. For the largest seagoing ships, rudder construction was complex and required huge timbers, the assembly sometimes weighing several tons (Steffy 1994:279).

Sag [Sagging]**.** The accidental rocker formed in a keel and bottom due to insufficient timbering or improper loading (Steffy 1994:279).

Scantlings. The principal timbers of a vessel (Steffy 1994:279).

Scarf [Scarph]**.** An overlapping joint used to connect two timbers or planks without increasing their dimensions (Steffy 1994:279).

Seam. The longitudinal joint between two timbers or planks; the term usually refers to planking seams, the longitudinal juxtaposition of the edges of planks in the sides or decks, which were made watertight (Steffy 1994:279).

Sheathing. A thin covering of metal or wood, to protect hulls from marine life or fouling, or to stabilize and protect surface material applied for that purpose. Sheathing was most commonly used in the form of copper, lead, zinc, or alloy sheets, or thin wooden planks known as *furring* or *deals* (Steffy 1994:279).

Sheathing nail. A small nail or tack used to attach sheathing to a hull (Steffy 1994:279).

Sheer. The longitudinal sweep of a vessel’s sides or decks (Steffy 1994:279).

Sheer line. Specifically, the line of the upper or main deck where it meets the side, but the term is often used to describe the sweep of the bulwarks or weather rail (Steffy 1994:279).

Sheer plan. The side view of a vessel’s hull plan (Steffy 1994:279).

Shelf [Shelf clamp, Shelf piece] (Steffy 1994:279).

Shell-first construction [Shell-built]**.** A modern (sometimes misleading) term used to describe the process by which all or part of the outer hull planking was erected before frames were attached to it. In pure shell-built hulls, outer planking was self-supporting and formed the primary structure; the framework fastened to it formed the secondary, or stiffening, structure (Steffy 1994:279).

Shipwright. A master craftsman skilled in the construction and repair of ships. In many instances, the person in charge of a ship's construction, including the supervision of carpenters and other personnel, control of expenditures and schedules, and acquisition of materials. Probably in many more areas and periods than have been documented, the term designated a formal title, such as the shipwrights to the English monarchs, or a level of expertise qualifying admission to a guild or association (Steffy 1994:279).

Shoe. A term variously applied to the cover for an anchor fluke or a protecting piece at the bottom of a keel or rudder. *See* **Anchor** and **False keel** (Steffy 1994:279).

Sided [Sided dimension]**.** The dimension of an unmolded surface; the distance across an outer frame surface, the forward or after surface of a (p. 1146) stem or sternpost, or the upper surface of a keel or keelson. *See* **Molded** for further information on timber dimensions (Steffy 1994:280).

Sister keelson. *See* **Keelson** (Steffy 1994:280).

Skeletal construction [Frame-first construction]**.** A modern (sometimes misleading) term used to describe the procedure in which hulls were constructed by first erecting frames and then attaching the outer skin of planking to them (Steffy 1994:280).

Spirketting. Thick interior planks running between the waterways and the **lining** (Steffy 1994:280).

Stanchion. An upright supporting post, including undecorated supports for deck beams and bulkheads (Steffy 1994:280).

Staple. A metal rod or bar whose sharpened ends were bent at right angles, used to fasten false keels to keels or to secure planking seams that tended to separate. Staples were used from the classical period to the present century (Steffy 1994:280).

Starboard. The right side of a vessel when facing forward (Steffy 1994:280).

Station lines [Body lines, Section lines]**.** The projections on a lines drawing that represent the various body shapes of a hull (Steffy 1994:280).

Stem [Stempost]**.** A vertical or upward curving timber or assembly of timbers, scarfed to the keel or central plank at its lower end, into which the two sides of the bow were joined (Steffy 1994:280).

Stern. The after end of a vessel (Steffy 1994:280).

Sternpost. A vertical or upward-curving timber or assembly of timbers stepped into, or scarfed to, the after end of the keel or heel (Steffy 1994:280).

Stocks. A structure supporting a vessel under construction or repair (Steffy 1994:280).

Strake [Streake]**.** A continuous line of planks, running from bow to stern (Steffy 1994:281).

Tenon. A wooden projection cut from the end of a timber or a separate wooden piece that was shaped to fit into a corresponding mortise. *See* **Mortise-and-tenon joint** (Steffy 1994:281).

Thick stuff. A term referring to the thick ceiling of the bottom (Steffy 1994:281).

Timber and room. *See* **Room and space** (Steffy 1994:281)**.**

Timbers. In general context, all wooden hull members; specifically, those members that formed the frames of a hull (Steffy 1994:281).

Treenail [Trunnel, Trennal]**.** A round or multi-sided piece of hardwood, driven through planks and timbers to connect them. Treenails were employed most frequently in attaching planking to frames, attaching knees to ceiling or beams, and in the scarfing of timbers. They were used in a variety of forms: with expanding wedges or nails in their ends, with tapered or square heads on their exterior ends, or completely unwedged and unheaded. When immersed, treenails swelled to make a tight fit (Steffy 1994:281).

Tumblehome [Fall home]**.** The inward curvature of a vessel's upper sides as they rose from the point of maximum breadth to the bulwarks. Tumblehome reduced topside weight and improved stability (Steffy 1994:281).

Turn of the bilge. The outboard part of the lower hull where the bottom curved toward the side (Steffy 1994:281).

Upper deck. The highest deck extending unbroken from bow to stern (Steffy 1994:281).

Wale. A thick strake of planking, or a belt of thick planking strakes, located along the side of a vessel for the purpose of girding and stiffening the outer hull (Steffy 1994:281).

Waterlines [Level lines]**.** Lines on a hull drawing representing the horizontal sections of the hull (Steffy 1994:281).

Waterway. A timber or gutter along the side of a deck whose purpose was to prevent the deck water from running down between the frames and to divert it to the scuppers (Steffy 1994:281).

Windlass. A horizontal cylinder, supported by bitts or brackets, used to haul anchors and hawsers (Steffy 1994:282).

Appendix 1

The data acquisition for this research is too extensive to be presented here in a readable format. All databases and spreadsheets are retained in digital format on the Flinders University's Archaeology 'H:Drive'. Additionally, the museums visited for this study also store digital copies of the data collected from their individual collections.

Edwin Fox Maritime Museum
Attn: collections manager
Address: Dunbar Wharf, Picton 7281, New Zealand
Phone: +64 3 573 6868
Email: info@edwinfoxship.nz

Mercury Bay Museum
Attn: collections manager
Address: 11a The Esplanade, Whitianga 3510, New Zealand
Phone: +64 7 866 0730
Email: info@mercurybaymuseum.co.nz

National Museum of the Royal New Zealand Navy
Attn: collections manager
Address: 64 King Edward Parade, Torpedo Bay, Devonport, Auckland 0624, New Zealand
Phone: +64 9 445 5186
Email: info@navymuseum.co.nz

Southland Museum and Art Gallery Niho o te Taniwha
Attn: collections manager
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Phone: +64 3 219 9069
Email: office@southlandmuseum.co.nz