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ORIGINAL ARTICLE

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Examining Nineteenth-Century British Colonial-Built Ships HMS *Buffalo* and *Edwin Fox*: Two Case Studies from New Zealand

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Abstract This article examines the archaeological timber remains from HMS *Buffalo* (built 1813), held in the Mercury Bay Museum, New Zealand, and the preserved hull of *Edwin Fox* (built 1853), sitting in dry dock in Picton, New Zealand. Both ships were constructed near Calcutta (Kolkata), India. Archaeological recording methodologies included detailed timber recording, dendrochronology, archaeometallurgy, organic resinous analyses, and wood-species and fiber identification. The results are then presented to highlight differences and similarities in resource choices and technological development pertaining to ship-construction elements. This contributes to understanding how shipwrights were adapting to new environments while maintaining their learned knowledge in a 19th-century colonial context.

Resumen En este artículo se examinan los restos arqueológicos de madera del HMS Buffalo (construido en 1813), que se encuentran en el Museo Mercury Bay, Nueva Zelanda, y el casco preservado del Edwin Fox (construido en 1853), que se encuentra en dique seco en Picton, Nueva Zelanda. Ambos barcos se construyeron cerca de Calcuta (Kolkata), India. Las metodologías de registro arqueológico incluyeron el registro detallado de la madera, la dendrocronología, la arqueometalurgia, los análisis de resinas orgánicas y la identificación de fibras y especies de madera. Luego se presentan los resultados para resaltar las diferencias y similitudes en la elección de recursos y el desarrollo tecnológico relacionado con los elementos de construcción de los barcos. Esto contribuye a comprender cómo los carpinteros navales se fueron adaptando a nuevos entornos manteniendo sus conocimientos aprendidos en un contexto colonial del siglo XIX.

Résumé Cet article examine les restes archéologiques de bois provenant du HMS Buffalo (construit en 1813), conservé au Musée Mercury Bay en Nouvelle-Zélande, et la coque préservée de l'Edwin Fox (construit en 1853), amarré en cale sèche à Picton, en Nouvelle-Zélande. Les deux navires ont été construits près de Calcutta (Kolkata) en Inde. Les méthodologies de relevés archéologiques ont inclus un enregistrement détaillé du bois, une dendrochronologie, une archéométallurgie, des analyses des résines organiques et une identification des fibres et des essences de bois. Les résultats sont ensuite présentés pour mettre en exergue les différences et similarités dans les choix des ressources et le développement technologique appartenant aux éléments de construction du navire. Cela permet de comprendre comment les charpentiers de marine s'adaptaient aux environnements nouveaux tout en maintenant leur savoir acquis dans un contexte colonial au 19ème siècle.

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Introduction

The nautical archaeological investigations of two vessels, HMS *Buffalo* (ex-*Hindostan*) and *Edwin Fox*, both constructed in Sulkea (colonial spelling)/Salkia (present spelling) opposite Calcutta/Kolkata, India, presents an opportunity to examine construction elements to understand early 19th-century British colonial shipbuilding processes (Fig. 1). The ships are now located in New Zealand with *Buffalo* shipwrecked in Mercury Bay, Whitianga and *Edwin Fox* preserved in dry dock at the *Edwin Fox* Maritime Museum in Picton (Fig. 2). These vessels were investigated as part a larger research project into the cultural transmission of construction technologies and design elements in 18th- and 19th-century British East India Company ships. The author accessed the museum collections related to the two vessels in the Mercury Bay Museum, Whitianga, which has on display several timbers from the *Buffalo* shipwreck site, and the *Edwin Fox* Maritime Museum. The *Edwin Fox* sits proudly on display in dry dock and its hull, both inside and outside, were accessible for recording.

The two ships, *Buffalo* (built 1813) and *Edwin Fox* (built 1853) were constructed 40 years apart in the first half of the 19th century. During this time, shipbuilding technologies were improving and being developed, as well as new timber resources being incorporated into the construction practices. To examine these developments, ship timbers from *Buffalo* and *Edwin Fox* were recorded and studied using a variety of methodologies, including ship-timber recording, wood-species identification, dendrochronology, metallurgical analysis, fiber identification,

Fig. 1 Location map of Sulkea/Salkia, India. (Map by Kurt Bennett, 2021.)

Fig. 2 Locations of *Buffalo* and *Edwin Fox*, New Zealand. (Map by Kurt Bennett, 2021.)

and organic resinous interpretation. Together, the results from the recording of ship materials informs us of how colonial shipwrights were incorporating new technologies and resources in shipbuilding and demonstrates their development over time in a colonial context.

HMS *Buffalo* (ex-*Hindostan*) (Built 1813)

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 in. (10.31 m) in beam by 15 ft. 8 in. (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). It was during this purchase the vessel was renamed HMS *Buffalo*. After the ship's service in war time, 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. On 14 June 1830, the Navy Board advised the Admiralty that the ship would be repurposed as a quarantine ship at Stangate Creek, Sheerness (Riddle and Bithell 2015:4; Bennett 2020).

In 1833, the Admiralty recommissioned the ship to continue the British colonial expansion into Australia and Aotearoa New Zealand, transporting convicts to Australia and on the return voyage to the northern hemisphere, sailing via New Zealand to load timber (Riddle and Bithell 2015:4). The ship was again recommissioned in 1836 and this time sailed from Britain to what was to be declared the province of South Australia on existing Aboriginal Country (Riddle and Bithell 2015:7). Proclamation of the new state happened on 28 December 1836 and Captain John Hindmarsh of *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 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 (Bennett 2021:84). 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 New Zealand in HMS *Herald* collecting signatures for Te Tiriti o Waitangi (Bennett 2021:85).

On 28 July 1840, while anchored in Cooks Bay, east of Whitianga, *Buffalo* was caught in a storm and dragged its anchor (Riddle and Bithell 2015:11). The ship subsequently lost its anchors and rudder, and ultimately the captain relinquished all control. Eventually, the ship was driven on shore and wrecked with the loss of two crew (Fig. 3).

Edwin Fox (Built 1853)

In October 1853, a team of British and Indian shipwrights completed the construction of *Edwin Fox* in the Reeves and Foster shipyard, Sulkea (Bennett 2018:82). On 9 December 1853, the completed vessel was issued with certificate number 12/1853 and registered at 835 tons, measuring 157 ft. (47.85 m) in length (LOA), 29 ft. (9 m) in breadth, and 21 ft.

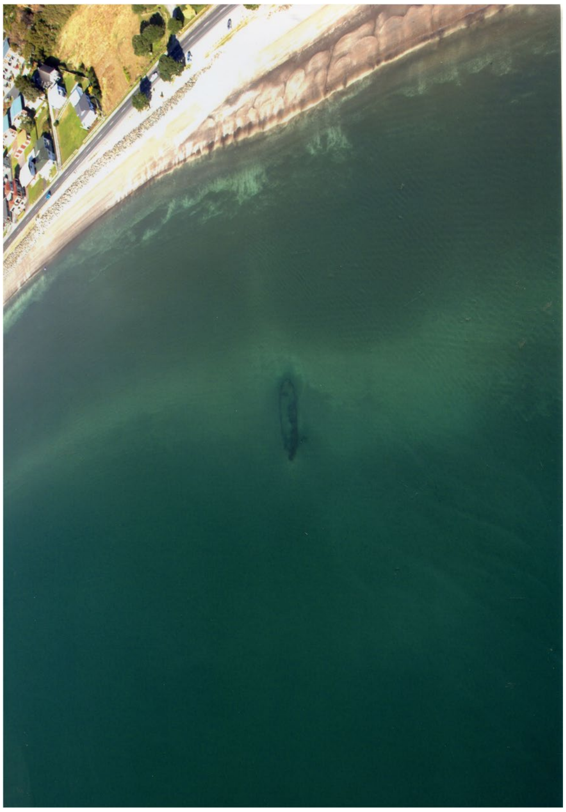

Fig. 3 *Buffalo* wreck site as seen from the air. (Image courtesy of the Mercury Bay Museum, 2018.)

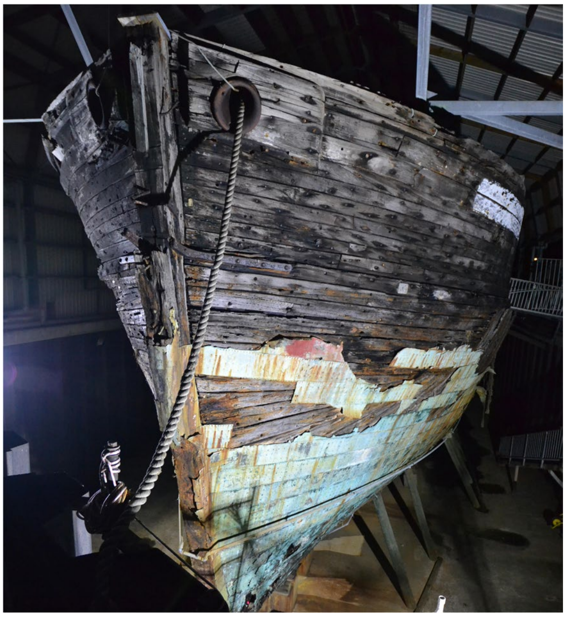

Fig. 4 *Edwin Fox* in dry dock. Notice the preservation of metal sheathing. (Photo by Kurt Bennett, 2017.)

6 in. (6.55 m) in depth (Costley 2014:33). The hull's construction employed teak (*Tectona grandis*) and sal (*Shorea robusta*) timber, and it was sheathed in Muntz (yellow) metal (Martin and Davey 1854; Mortiboy et al. 2003).

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 (Locker-Lampson and Francis 1979:30). 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. Then in 1873, the vessel transported immigrants between Britain and New Zealand until 1880 (Locker-Lampson and Francis 1979:30–31; Costley 2014:140). Shortly after the ship's final voyage transporting immigrants to New Zealand, the ship was converted into a refrigeration meat store and moored in ports around the country (Costley 2014:152–153). Around 1900, *Edwin Fox* became a permanent feature in Waitohi Picton and its rigging cut down. The New Zealand Refrigeration Company converted the vessel into a storage ship storing frozen animal carcasses. The ship then served as a coal hulk to fuel the land-based freezer boiler systems (Locker-Lampson and Francis 1979:30–31).

In 1965, the newly formed *Edwin Fox* Society purchased *Edwin Fox* for one shilling (NZ$1.96, 2017) from the New Zealand Refrigeration Company and had it moored along Picton's waterfront. The museum building was built alongside in 1986, and the vessel remained floating until 1999 (Costley 2014:186). 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 (Fig. 4).

Methodologies

This section briefly describes the methods employed in this research to collect data for comparison between *Buffalo* and *Edwin Fox*. This included disarticulated and preserved hull-timber recording methods, wood sampling and identification, dendrochronology, metal analyses, fiber identification, and organic analyses.

Disarticulated Hull-Timber Recording

The Mercury Bay Museum presented several disarticulated hull timbers in its *Buffalo* collection. These timbers were a possible deck knee, false keel, futtock, and sacrificial timber sheathing. The timbers underwent detailed recording, including the recording of their dimensions, identifying function, determining types of fasteners, and general observations. These were entered into a specially designed electronic database on an iPad. Each timber was then photographed and drawn to scale.

Preserved Hull Recording

The historic *Edwin Fox* timber 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 drydock. The current condition of the hull presented a large and complex object to record for this study. Therefore, different recording methodologies were used to record the shape of the vessel and its construction technologies. These included recording a cross section of midships and individual timbers through base line offset. This resulted in recording dimensions and diagnostic features of individual timbers while in context.

A team of maritime archaeologists, Katarina Jerbić, Matthew Carter, and the author, recorded the midship section of the *Edwin Fox* hull using the baseline offset method (Fig. 5). The team first established the location of the midship by calculating the middle between the forward and aft perpendiculars. A baseline was established along the *x* axis underneath the hull and extended from the dry dock's west wall to the east wall. Two baselines were then established along the *y* axis on the 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).

Once the recording of external hull points was completed, the midship line was transferred to inside

Fig. 5 Katarina Jerbić and Matthew Carter recording the underside of the *Edwin Fox* hull. (Photo by Kurt Bennett, 2017.)

the vessel's hull. From this line, three baselines were established in the interior. One baseline followed the *x* axis, traversing the keelson, floor timbers, framing, and ceiling planking. The *y*-axis baselines then intersected the *x*-axis baseline and extended vertically up both the port and starboard internal sides of the ship. 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.

All measurements were plotted onto an A1-size drafting film to a scale of 1:20. The midship section was drawn on site at the time of recording to ensure any mistakes could be rectified. The finished drawing was then digitized and saved in both JPEG and TIFF file formats. These digital copies were then cleaned up in Adobe Illustrator CS6 for final publication.

Material Sampling and Identification

The two ship's hull timbers recorded for diagnostic features were sampled to identify timber species. Extraction methods included making two parallel cuts using a hand saw into the timber and then chiselling out the sample. 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, the same as previously described and the second method involved drilling cores for dendrochronology that would also be used to identify the wood. Timber specialist, Rod Wallace, University of Auckland Te Whare Wānanga o Tāmaki Makaurau, inspected the timber samples.

Metal sheathing samples were collected from both vessels, and they measured approximately <1 cm^3. Additionally, a representative sample of sheathing tacks from *Edwin Fox* was collected 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 analyze surface topography, collect backscattered electron images, and characterize 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.

Representative fiber samples collected from *Edwin Fox* measured approximately 3 cm^2 in area. Samples were analysed with a transmission light microscope with a polarized light option. The hairs and fibers were identified using identification guides and reference collections of animal hair and plant fibers at BIAX Consultancy in the Netherlands. No fibers were available for sampling on the *Buffalo* timbers.

The resinous samples collected from *Buffalo* and *Edwin Fox* were analyzed by Jordan Spangler of the School of Chemistry and Physical Sciences at Flinders University, South Australia. Prolysis-gas chromatography was used to analyze the resinous compounds. This method involved the chemical analysis of the sample through heating it and dividing it into smaller molecules.

Dendrochronology

Dendrochronology was only conducted on the *Edwin Fox* hull because the timbers were suitable for extracting the 50+ tree rings required for counting and statistical analysis. Gretel Boswijk, a dendrochronologist and senior lecturer in Environment, Faculty of Science, University of Auckland Te Whare Wānanga o Tāmaki Makaurau, assisted with the coring using standard methods (Boswijk 2009; Boswijk and Jones 2012; Boswijk et al. 2014; Boswijk and Johns 2018). Timbers at midships were cored, with each sample labelled with prefix "EFX" followed by sequential numbers as the cores were extracted.

For the tree rings to be counted, each sample was sanded and polished—exposing the tree rings in cross-section. Each ring was counted by visually inspecting the sample under microscope and the distance between each ring was electronically measured and recorded on specialist software, TsapWIN. Statistical analysis calculated which core samples related to each other in terms of species and were then compared to master chronologies of "Burma Teak," "Java Teak," and "Thai Teak" provided by Martin Bridge (Institute of Archaeology, University College of London).

Buffalo **Results**

A total of 15 timbers were recorded. The recorded timbers and their dimensions are summarized below in Table 1. The timbers included a possible deck knee, a false keel, a possible futtock, and sacrificial timber sheathing. The maximum timber measurements represent their full preserved extents and were recorded during the fieldwork for this research.

Material Analyses and Identification

Buffalo wood samples were collected for identification. This was conducted 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, 9 samples were collected from the 15 recorded timbers. These are summarized below in Table 2.

Table 1 Summarized *Buffalo* timber dimensions, Mercury Bay Museum

ID	Accession No.	Feature	Length (mm)	Molded/ Width (mm)	Sided (mm)	Thickness (mm)	Fastener types
BUF_001	2019.001.01	Sacrificial sheathing	3193	**209**	N/A	**24**	Possible ferriferous nails
BUF_002	2019.002.01	Sacrificial sheathing	1050	131	N/A	28	Not recorded
BUF_003	2019.005.01	Sacrificial sheathing	3613	240	N/A	**23**	Ferriferous nails
BUF_004	1980.016	Sacrificial sheathing	818	222	N/A	**27**	Not recorded
BUF_005	1980.004	Sacrificial sheathing	570	127	N/A	19	Not recorded
BUF_006	2019.003	Sacrificial sheathing	1194	123	N/A	25	Possible ferriferous nails
BUF_007	2019.004	Sacrificial sheathing	1840	228	N/A	**25**	Ferriferous nails
BUF_008	1980.016	Undetermined	345	175	80	N/A	Treenail
BUF_009	None	Sacrificial sheathing	618	184	N/A	21	Ferriferous nails
BUF_010	3258	Undetermined	709	89	41		Not recorded
BUF_011	1996	Outer plank	677	165	N/A	46	Treenails
BUF_012	865	Undetermined	635	148	107	N/A	Not recorded
BUF_013	230313/8	Knee	930	90	85	N/A	Ferriferous nails
BUF_014	31895/10	False keel	2040	**345**	**90**	N/A	Possible staples
BUF_015	None	Futtock	860	**155**	**212**	N/A	Treenails

Note: **Bold** = maximum original measurements; N/A = not available.

Table 2 Timber identification for *Buffalo* ship timbers

Artifact No.	Accession No.	Scientific name	Common name	Feature
BUF_001	2019.001.01	*Cedrus* spp.?	Cedar	Possible plank
BUF_002	2019.002.01	*Cedrus* spp.?	Cedar	Possible plank
BUF_003	2019.005.01	*Cedrus* spp.?	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* spp.?	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

It was decided by the metal expert that three sheathing samples would be analyzed to reflect a representative sample set of the total seven metal samples collected. Thus, only three samples are presented here. Each sample was tested three times to ensure they are characteristic. The three areas chosen for each sample were those that displayed solid metal and were relatively free of any surface corrosion. The results from the analysis are presented in Table 3.

The analysis of the sheathing fragments confirms *Buffalo*'s hull was covered with copper sheets. Copper weight percentages vary between 98.32% and

Table 3 HMS *Buffalo* sheathing elemental composition results

Description	Wt %											Atomic %										
	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb	Bi	Total	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb	Bi	Total
Sample BUF_1M1: spectrum 1	0.11	0.00	99.00	0.00	0.44	0.00	0.16	0.18	0.00	0.10	100	0.13	0.00	99.28	0.00	0.37	0.00	0.09	0.09	0.00	0.03	100
Sample BUF_1M1: spectrum 2	0.21	0.02	99.06	0.14	0.51	0.03	0.01	0.00	0.04	0.00	100	0.24	0.02	99.15	0.13	0.43	0.01	0.01	0.00	0.01	0.00	100
Sample BUF_1M1: spectrum 3	0.18	0.02	98.76	0.05	0.78	0.19	0.00	0.00	0.00	0.03	100	0.20	0.02	98.95	0.05	0.66	0.11	0.00	0.00	0.00	0.01	100
Sample BUF_2M1: spectrum 1	0.21	0.05	98.73	0.02	0.71	0.00	0.10	0.12	0.00	0.06	100	0.24	0.05	98.95	0.02	0.60	0.00	0.05	0.06	0.00	0.02	100
Sample BUF_2M1: spectrum 2	0.32	0.10	98.32	0.00	0.89	0.12	0.07	0.00	0.13	0.05	100	0.37	0.11	98.60	0.00	0.76	0.07	0.04	0.00	0.04	0.01	100
Sample BUF_2M1: spectrum 3	0.34	0.11	99.00	0.06	0.41	0.07	0.00	0.00	0.00	0.00	100	0.38	0.12	99.04	0.06	0.35	0.04	0.00	0.00	0.00	0.00	100
Sample BUF_3M1: spectrum 1	0.13	0.05	99.02	0.02	0.46	0.22	0.07	0.01	0.00	0.01	100	0.15	0.06	99.21	0.02	0.39	0.13	0.04	0.01	0.00	0.00	100
Sample BUF_3M1: spectrum 2	0.18	0.00	99.07	0.00	0.67	0.00	0.00	0.04	0.02	0.02	100	0.21	0.00	99.19	0.00	0.57	0.00	0.00	0.02	0.01	0.00	100
Sample BUF_3M1: spectrum 3	0.08	0.00	99.04	0.04	0.43	0.26	0.00	0.01	0.13	0.00	100	0.10	0.00	99.30	0.04	0.37	0.16	0.00	0.01	0.04	0.00	100

99.07%. The copper is pure and unalloyed. It does contain some carbon, which is a known corrosion product and therefore omitted from the spectra. For comparative examples from other international case studies and research, see McAllister et al. (this issue) and Philpin et al. (2021).

Here disarticulated pieces of metal sheathing from the museum's *Buffalo* collection that were not attached to any other timber/hull material are presented. Table 4 summarizes the pieces of sheathing that displayed maker's marks or stamps.

Of note, sheathing 008 recorded a maker's stamp, likely to be a Muntz-metal stamp. The stamp showed the number "40" and "MUN" following a circular outline around the epicenter (Fig. 6). While the Muntz metal could not be definitively associated with the *Buffalo* shipwreck due to limited provenancing information/museum records, it could equally have been an isolated repair to the vessel's sheathing reflecting its later voyages of the 1830s. Additionally, the sheet's color is distinctly different from the other recorded sheets, being an oxidized-green color compared to the other sheets' red luster.

No fiber was present on the timbers at the time of recording. Therefore, no samples were collected for identification.

Five timbers (BUF 001, BUF 002, BUF 003, BUF004 and BUF 007), identified as sacrificial timber planks, contained a pitch-like layer between the timber and metal sheathing. All five samples returned successful results and indicated the resinous substances were predominately hydrocarbon based and probably derived from coal.

Summary

The timbers recorded for *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 *Buffalo* collection. None of the timbers had complete lengths as they were either broken or have been cut. Three timbers presented maximum molded 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 utilized several different genera of wood, including teak, oak, and cedar and/or pine. Interestingly, the

Table 4 Sheathing summary

Artifact No.	Feature	Accession No.	Stamps	Sampled	Description
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 center, 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 center, and “183…” along the bottom.

oak futtock appears to be an outlier when compared to other southeast timber selection and may reflect later refitting of the ship for transporting people, i.e., troops, convicts, immigrants. Material analyses confirm the hull was sheathed in copper sheets with a layer of hydrocarbon pitch between the metal sheets and sacrificial timber planks. No fibers were extant for recording.

Edwin Fox Results

In April 2017, onsite fieldwork produced the data for a cross-section drawing of midships (Fig. 7). 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.

The cross-section highlights different constructional elements; however, for comparison with *Buffalo* only the false keel, keel, futtocks, ceiling planking, and outer hull planking is described here (Table 5). 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. The ceiling planks continue longitudinally from bow to stern up the side of the hull toward the gunwales. 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.

Material Analyses and 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 6).

A total of nine samples, including metal sheathing and a sheathing tack, were collected for analysis. Only two sheathing samples were analyzed as a representative sample of the sheets that covered the hull. The results from analyses are presented in Tables 7, 8, and 9.

The sheathing of *Edwin Fox* is consistent with that of Muntz-metal compositions. The sheathing recorded a composition of 33.41%–35.73% zinc and 64.27%–66.59% copper. The tacks that fastened the sheathing were manufactured using 72.63%–74.36% copper, 23.89%–25.77% zinc and some tin varying from 1.59% to 1.77%. The concentration of copper registered greater than the sheathing while including a little zinc.

A metal patent stamp located on the starboard side aft of midships identified the manufacturer of the sheathing. The sheathing stamp was circular and read: 45\MUNTZ’S PATENT\45 and 18 in the center of the stamp (Fig. 8). Other areas on the hull were searched for patent stamps; however, the established corrosion layer made it difficult to identify additional

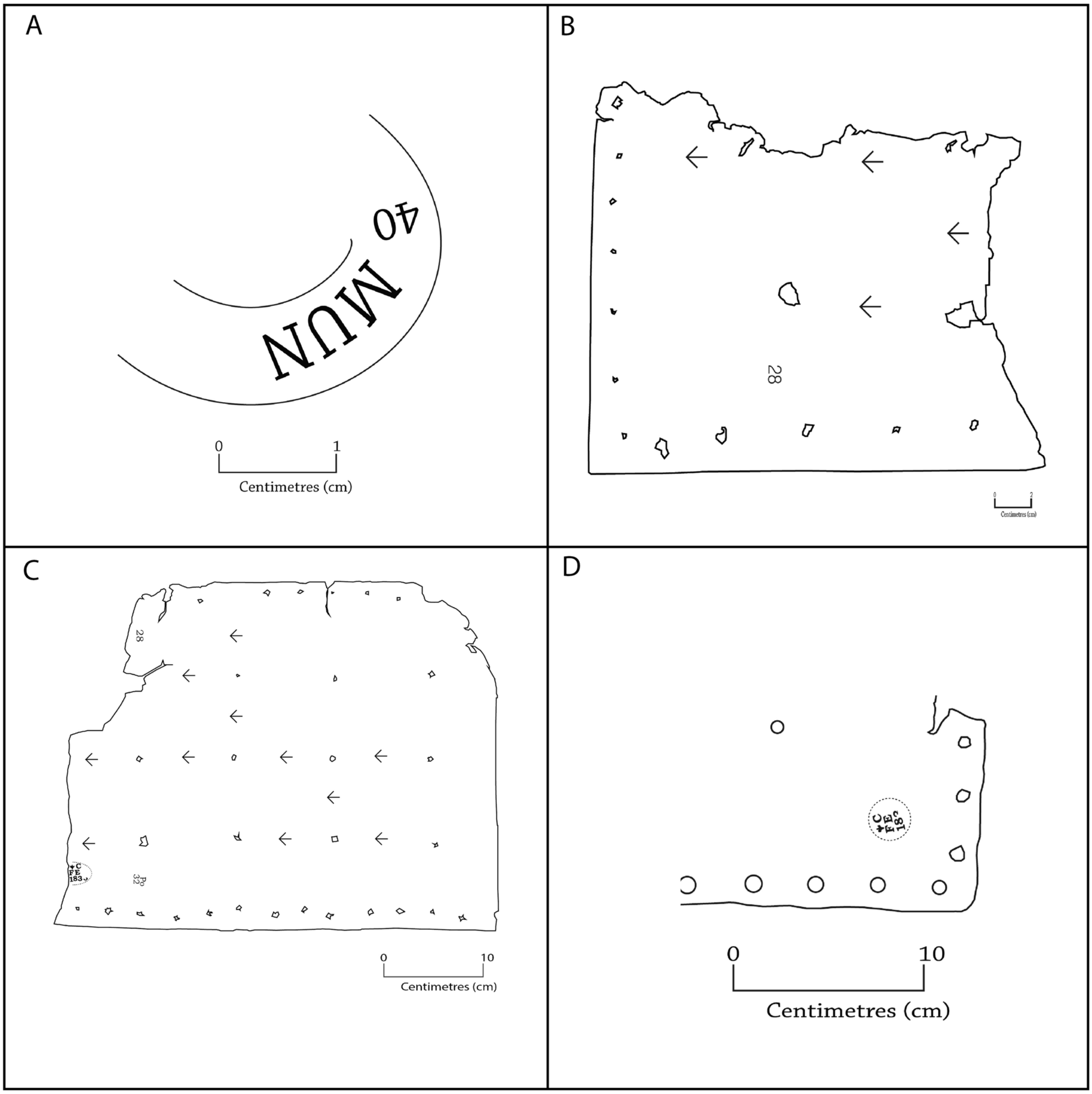

Fig. 6 (*A*) *Buffalo* sheathing stamp 008, (*B*) *Buffalo* sheathing stamp 009, (*C*) *Buffalo* sheathing stamp 010, and (*D*) *Buffalo* sheathing stamp 011. (Images by Kurt Bennett, 2018.)

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.

Two fiber 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 fiber matting placed between the two layers of outer hull planks. This fiber had no identifiable weave and the packing of the fibers 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 fiber's function served as caulking creating a watertight seal

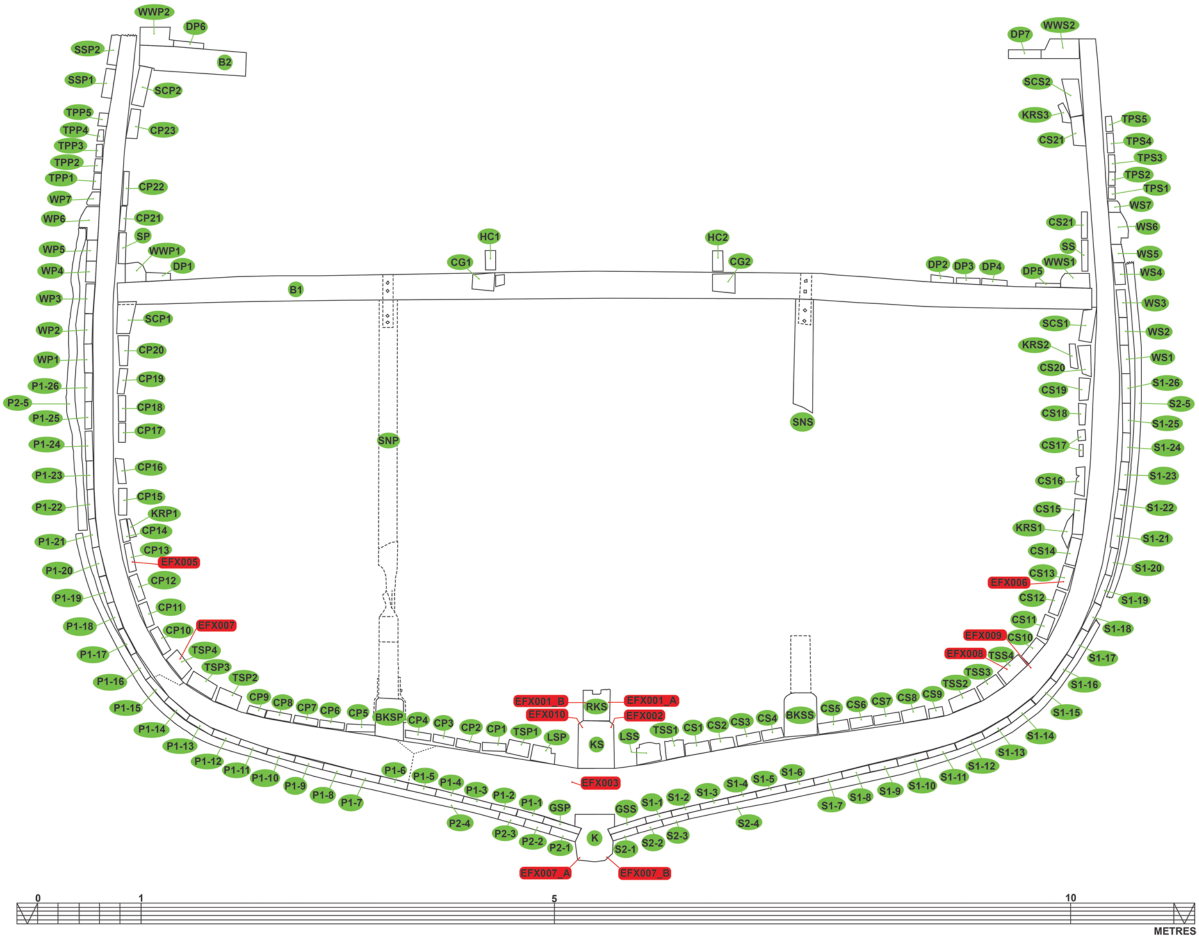

Fig. 7 Cross-section of *Edwin Fox*'s midship. Key: B=beam, BKS=bilge keelson, CG=carling, C=ceiling planking, D=decking, GS=garboard strake, HC=hatch combing, K=keel, KR=knee rider, KS=keelson, LS=limber strake, P=exterior planking (portside), RKS=rider keelson, S=exterior planking (starboard), SC=shelf clamp, SN=stanchion, SP & SS=spirketting, SS=sheer strake, TP=topside planking, TS=thick strake ceiling, W=wales, and WW=waterways. the suffixes denote "P"=portside and "S"=starboard. (Image by Kurt Bennett, 2018.)

Table 5 Timber hull features recorded on *Edwin Fox*

ID	Feature	Length (mm)	Molded/Width (mm)	Sided (mm)	Thickness (mm)	Fastener types
FK	False keel (mm)	Not recorded	342	115	NA	Possible metal bolts
K	Keel (mm)	Not recorded	345	440	NA	Possible metal bolts
F	Futtocks (mm)	Not recorded	280	170–570	NA	Possible metal fasteners (unidentified type) and treenails
CP & CS	Ceiling planking (mm)	Not recorded	248.63–248.84	NA	77.82–95.68	Ferriferous dumps and treenails
P1 & S1	Outer planking (Layer 1)	Max. 20.36 m	277.3	NA	63.15	Unrecorded
P2 & S2	Outer planking (Layer 2)		250	NA	77.6	Copper-alloy bolts and treenails
NA	Sacrificial planking	None	None	None	None	None

Table 6 *Edwin Fox* wood identification

Sample No.	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, center	*Shorea robusta*	Sal	Floor timber
EFX004_A	M	Main mast, center	*Cedrus deodara*	Himalayan cedar	Main mast
EFX004_B	M	Main mast, center	*Cedrus deodara*	Himalayan cedar	Main mast
EFX005	CP13	Midship, port	*Tectona grandis*	Teak	Plank (No. 18)
EFX006	CS13	Midship, starboard	*Tectona grandis*	Teak	Plank (No. 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 (No. 14) (thick strake)
EFX009	-	Midship, starboard	*Shorea robusta*	Sal	Frame (possible No. 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	Outermost timber planking directly beneath metal sheathing

Table 7 *Edwin Fox* hull sheathing elemental composition results

			Wt%			Atomic %		
Museum No.	Analysis No.	Description	Cu	Zn	Total	Cu	Zn	Total
EFX_CS1	Sample CS001: spectrum 1	Sheathing, portside bow.	64.46	35.54	100	65.11	34.89	100
EFX_CS1	Sample CS001: spectrum 2		64.47	35.53	100	65.12	34.88	100
EFX_CS1	Sample CS001: spectrum 3		64.27	35.73	100	64.92	35.08	100
EFX_CS2	Sample CS002: spectrum 1	Sheathing, portside midships.	65.06	34.94	100	65.70	34.30	100
EFX_CS2	Sample CS002: spectrum 2		66.59	33.41	100	67.22	32.78	100
EFX_CS2	Sample CS002: spectrum 3		65.81	34.19	100	66.44	33.56	100

Table 8 *Edwin Fox* elemental composition of white spots in the Muntz-metal sheathing

			Wt%				Atomic %			
Museum No.	Analysis No.	Description	Cu	Zn	Pb	Total	Cu	Zn	Pb	Total
EFX_CS2	CS002: spectrum 4	Sheathing, portside midships.	5.46	4.02	90.52	100	14.69	10.53	74.77	100

Table 9 *Edwin Fox* elemental composition of the sheathing tacks

			Wt%				Atomic %			
Museum No.	Analysis No.	Description	Cu	Zn	Sn	Total	Cu	Zn	Sn	Total
EFX_CS-009	CS009.1: spectrum 1	*Edwin Fox* rudder sheathing tack, starboard.	72.63	25.77	1.59	100	73.72	25.43	0.86	100
EFX_CS-009	CS009.2: spectrum 1		74.36	23.89	1.77	100	75.47	23.56	0.95	100

Fig. 8 A Muntz stamp recorded on the *Edwin Fox* hull. (Photo by Kurt Bennett, 2017.)

between two planks. The results of the fiber identification are presented below in Table 10.

A third fiber sample consisting of different fibers was collected from the organic compound between the metal sheathing and the second hull planking layer. Different fibers exist within the pitch-like compound. Therefore, three visually different fibers were collected for analysis in order to understand the types of fibers included in the organic layer applied between the metal sheathing and outer planking. These results are summarized in Table 11.

Identification conducted by BIAX revealed that there was no animal hair evident in the organic compound layer (Sample EF-003). The fibers are all plant based. EF-003-C was of notable difference with the appearance of twisted fibers, such as rope. Combined, these fibers are mixed with a resinous compound.

Table 10 Fiber samples from *Edwin Fox*

Sample No.	Function	Fiber	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.

Sample EF_001_O1 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 fibers which have been identified previously. The second layer of goat hair matting between the first and second layer of timber planks did not contain any resinous substance. 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 fibers, which is different from the other samples collected from *Buffalo*.

Thirteen midship timbers cored for dendrochornology included the keel, the keelson, the rider keelson, a floor timber, ceiling planking, a frame, and the main mast. Overall, 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. The results for cross-dating with the master chronologies, however, were inconclusive. The cores failed to provide a high value coefficient sufficient to determine a date range for the tree(s).

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

Table 11 Fibers identified in the organic compound layer between the metal sheathing and outer planking layer on *Edwin Fox*

Sample No.	Function	Fiber	Notes
EF-003-A	Fiber mixed with organic compound between metal sheathing and outer planking.	Jute	Bast natural fibers.
EF-003-B	Fiber mixed with organic compound between metal sheathing and outer planking.	Twig?	Tiny fragment of wood with rootlets.
EF-003-C	Fiber mixed with organic compound between metal sheathing and outer planking.	Jute	Processed bast fibers. Twisted fibers, probable offcuts from rope.

constructed using teak, sal, Himalayan cedar, and elm timbers. The hull was sheathed using Muntz-metal sheets with an added layer of fiber and pitch.

Discussion

The *Buffalo* collection at the Mercury Bay Museum was scrutinized by the author 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.

The *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 *Buffalo*. Material collected on *Buffalo* Beach is most probably from the *Buffalo* wreck because it is the only known large timber shipwreck in the vicinity. It is, therefore, more than probable that the timbers and metal sheathing included in this study are from the *Buffalo* shipwreck. Additionally, a follow up survey of the shipwreck and material analysis conducted in 2021 will assist in provenancing the museum's *Buffalo* timber collection (Bennett et al. 2021).

It is also worth noting the *Buffalo* timbers recorded for this investigation have not been through previous controlled conservation treatment. The timbers were dried out naturally while either in private possession or when stored in the museum. Upon inspection during the recording, the timbers did not appear to be distorted that would affect measuring or their identification. However, it is probable shrinkage has occurred as a result of the drying process due to evidence of cracking. Overall, the change in timbers' dimensions was assessed to be minimal with variation likely measuring in millimeters and this should be considered for any future comparative studies. The shapes themselves appeared to be well-preserved and aided in identification of the museum's collection.

Edwin Fox is the last remaining preserved hull available for the study of British colonial-built merchant ships of the mid-19th 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.

Vessel Assembly

Timbers

The following discussion highlights several key timbers that were recorded on both vessels with similar features and dimensions for comparison. Table 12 summarizes the results collected from *Buffalo* and *Edwin Fox*.

False Keel and 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. *Buffalo*'s and *Edwin Fox*'s false keels are both hewn from teak trees. The false keel sections showed box timber joints where each timber was connected to the next. The box joint is a simple link that is easily crafted and therefore provided easy fitting for the individual false keel pieces.

No archaeological remains of *Buffalo*'s keel were available for recording in the museum collection. To understand the possible size of the keel, the moulded

Table 12 Summarized details and results collected from *Buffalo* ship timbers and *Edwin Fox*'s preserved hull

Vessel	*Buffalo* (ex-*Hindostan*)	*Edwin Fox*
Year built	1813	1853
Shipyard	Bonner & Horsburgh, Sulkea/Salkia, Calcutta/Kolkata	Reeves, Union Dock, Sulkea/Salkia, Calcutta/Kolkata
Length	120 ft. (36.57 m)	144 ft. (43.89 m)
Breadth	33 ft. (10.05 m)	29 ft 8 in. (9 m)
Tons	589	835
False keel (l × m × s) (mm)	? × 345 × 90	? × 342 × 115
Keel (s × m) (mm)	? × 345	440 × 345
Futtocks (s × m) (mm)	155 × 212	170–570 × 280
Ceiling planking (w × t) (mm)	300 × ?	248.63–248.84 × 77.82–95.68
Outer planking (mm)	Unrecorded	Layer 1 = 277.3 × 63.15 Layer 2 = 250 × 77.6
Sacrificial planking (w × t) (mm)	209 × 24.8	None
Fasteners	Treenails and metal	Treenails and metal
Wood	Teak, oak, cedar, and pine.	Teak, sal, Himalayan cedar
Metal sheathing	Pure copper	Muntz metal
Fibers	Not recorded	Goat hair and hemp
Pitch	Hydrocarbon-based tar	Pine and coal tar

Note: l = length, m = molded, s = sided, w = width, t = thickness, mm = millimeters

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*, however, was intact from bow to stern and measured a maximum 42.48 m. Its sided measurement was also the same as *Buffalo*'s which may suggest a standardized dimension of ship's keels. Regardless of the ship's overall size, similar dimensions have been applied to the vessel's keels.

Futtocks *Buffalo* had one futtock timber fragment for recording, and *Edwin Fox* with its preserved hull presented molded and sided dimensions. Over time, the molded dimension increased by >20 mm from *Buffalo* to *Edwin Fox*. This smaller dimension in *Buffalo*'s futtock sizing 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. However, it is argued here that futtocks across 40 years of shipbuilding from the same geographic locations remained relatively standard.

Ceiling Planking Ceiling planks are absent from the *Buffalo* collection used for this research. Instead, approximate widths extracted from an 1980s site plan (Jeffery 1988) are included in this discussion. The thickness, however, could not be measured as the plan view is two-dimensional.

Specific to *Edwin Fox*, the ceiling planks were sawn to the same standardized widths, whereas the thicknesses seem to vary. This could be caused by several factors, including timber availability, processing by different suppliers and thicknesses may have been affected by environmental processes over time. Finally, when compared with *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.

Outer Hull Planking The Mercury Bay Museum *Buffalo* timber collection did not have any outer hull planks available for recording. Therefore, the vessel's hull planking dimensions are not discussed here.

Edwin Fox, on the other hand, recorded two outer layers of hull planking in situ. The first layer of hull planking measured an average 277.30 mm wide by 63.15 mm thick and was sawn 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 ca. 1869 (Weymouth 1869). Thus, the archaeological recording probably reflects this last repair to the ship.

In the late 18th century Gabriel Snodgrass (1797:3) recommended, instead of a major repair, that the bottom and upper works of a British vessel is "doubled with three-inch oak plank, from keel to gunwale." This technique became known as "doubling" and was used throughout the 19th century for deficient hulls (Sexton 1991:60; Milne et al. 1998:75). 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.

Sacrificial Planking Sacrificial planking "were a very necessary protection for the ship's hull in hot climates against the insidious attacks of the worm" (Chatterton 1912:82). *Buffalo*'s timber sheathing was identified as cedar. 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 *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 19th 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" (Martin 1854). Thus, according to the historical 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 (Weymouth 1869). The Muntz's 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 later in this article.

Fasteners

Michael McCarthy (2005:25) defined a treenail's function as fastening planking to the ship's upright timbers. The treenails recorded for this study were evident in ceiling planking, outer hull planking, and futtock timbers. *Buffalo*'s treenails measured ca. 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 standardized 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.

The use of treenails in colonial shipbuilding is highlighted by Ball (1995:53): "Treenails were not favored 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 both *Buffalo* and *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-19th century in British merchant vessels.

Sheathing Tacks

Tacks are used on the two case studies to attach metal sheathing to the outside of the ships' hulls. McCarthy (2005:175) described these fasteners as "very small nails" measuring ca. 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 case studies displayed similar dimensions with variations up to

Fig. 9 *Buffalo* (*left*) and *Edwin Fox* (*right*) sheathing tacks. (Photo by Kurt Bennett, 2020.)

34 mm in length. The apparent differences between the tacks are the shapes of the shanks and methods of manufacture (Fig. 9). By the early 19th century, manufacturing processes improved, as the evidence from the *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-19th 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 (Ronnberg 1980). Archaeological evidence from the 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 labor-intensive process to a mechanized manufacturing process.

Metal Sheathing

The results highlight that pure copper sheathing was used for *Buffalo*, whereas *Edwin Fox* was sheathed in Muntz metal. This adoption of sheathing materials reflects the historical record and development of antifouling technology.

The exact cause for the carbon inclusions in the *Buffalo* sheathing samples is unknown. The sheathing fragments did not receive any conservation treatment after they were removed from the shipwreck site, so it is most likely corrosion product. 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 1846, patent 11410 was issued to George Fredrick Muntz, Sr., 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). The sheathing-metal analysis showed 33.41%–35.73% zinc and 64.27%–66.59% copper, which shows a higher percentage weighting toward copper and no lead was present. Therefore, it is inconclusive if *Edwin Fox* was sheathed using the 1846 patent for Muntz metal (van Duivenvoorde et al., this issue).

The inclusion of all three elements—copper, zinc, and lead—suggest *Edwin Fox*'s sheathing was probably manufactured using the second Muntz's metal patent of 1846, but it has no added lead to the alloy.

Edwin Fox's sheathing displayed a Muntz Patent stamp reading: 18 in the center with 45 on either side. The central number indicates the weight of the sheet at 18 oz./ft.^{2}, 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. Meade (1869:399–400) stated that "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*.

Stamps recorded on early 19th-century sheathing help to identify where and when the ship was last sheathed. *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, *Buffalo*'s hull was coppered in Chatham Dockyard in 1833 using naval copper sheathing weighing 28 oz. per sheet. The broad arrows reflect the vessel employed as a naval vessel. 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. It is probable "Po32" represents the date the sheet was rolled, i.e., 1932. Around 1805 the Admiralty started to recycle copper in its Portsmouth Dockyard rolling mill, however; after 1805 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 *Buffalo*'s copper sheathing was recycled in Portsmouth Dockyard before it arrived in Chatham Dockyard to be used on the ship's hull.

Fibers

Edwin Fox contained packed strands of hemp caulking in the seams between planks. The quality of hemp appears to be adequate for creating a watertight seal. This is reflected in the fact *Edwin Fox* had a long sailing career, being reused for several purposes before becoming a static museum display.

A fibrous compacted matting exists only on *Edwin Fox*. This is located between the two layers of hull planking. The fibers 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. 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.

Pitch

The chemical results of the two 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 chemical binders. Dehydroabietic acid is naturally occurring and is derived from woody plants, specifically conifers (Wilkins et al. 1992:1).

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 sulfur, which is naturally occurring and likely to be associated with the hydrocarbon compounds. Therefore, this compound probably reflects British practices as the ship was last sheathed at Chatham Dockyard ca. 1833, rather than natural waxes and oils documented in India.

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 fibers and this suggests shipwrights were applying pitch with 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).

It is possible that *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.

Conclusion

The two vessels, *Buffalo* and *Edwin Fox* reveal similarities and differences in colonial ship development. During the early 19th century to the mid-19th century, design parameters and timber dimensions remain consistent. It is likely that colonial 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 industrialized 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 localized shipbuilding communities. 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, British colonial ships began a new era of innovation, adoption, and refinement.

Conflict of Interest

The author states there is no conflict of interest.

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