

Sewn boats in the Qatar Museums collection, Doha: *baggāras* and *kettuvallams* as records of a western Indian Ocean technological tradition

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Vernacular sewn boats from southern Iran and Kerala, India, in the collection of Qatar Museums are documented and their construction described. The Iranian *baggāras* are unique preservations of sewn boats from the Arabian-Persian Gulf, notable for their previously undocumented keel-garboard sewing technique and extensive use of bitumen coatings. Comparison between individual boats enables conclusions to be drawn about the builders' conception, as well as variation within the type. The Keralite *kettuvallams* represent an ongoing vernacular tradition that is nevertheless poorly documented or preserved in museum contexts. Construction drawings, naval-lines drawings, and 3D photogrammetry models are provided for all vessels.

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Recent acquisitions by Qatar Museums (QM), the state museums, archaeology and heritage organization of Qatar, have added a number of sewn boats to its existing collection of watercraft from the Arabian-Persian Gulf and Oman. Five are fishing *baggāras* (Arabic بَغَارَة, pl. بَغَائِر or بَغَارَات) from the Gulf, while two others are a variety of *kettuvallam* from Kerala, India. The acquisitions are a rare instance of preservation of significant examples of a broadly western Indian Ocean tradition that is today limited only to parts of India (Moreland, 1939a; 1939b: 63–64; Hornell, 1941; 1942: 22; Hourani, 1995 (1951): 92–93; Bowen, 1952: 202; Prins, 1982; 1986: 64–

94, 100–111; Adams, 1985; Kentley, 1985; 1996; Kapitän, 1987: 135–148; 2009: 66 ff.; Kentley and Gunaratne, 1987: 35–48; Shihab, 1987: 41–58; Varadarajan, 1993; 1998; Vosmer, 1993; 2005: 236; 2019: 305; Prados, 1996: 99; Flecker, 2000: 199–200; 2001: 336–337; 2011: 101; McGrail, 2001: 71–72; Agius, 2002: 78–81; 2008: 138–140, 148–150; Rajamanickam, 2004: 68–71, 87–88, 139–140, 187–192; Camelin, 2006: 103–108; Ransley, 2009: vol. 1, 88–125, vol. 2, 10–127 (*passim*); 2012; Shaikh *et al.*, 2011; Jansen van Rensburg, 2016: 114–115; Burningham, 2019; Dixon, 2019; Fenwick, 2015; 2019; Ghidoni, 2019: 375; Shaikh, 2019: 377; Staples and Blue, 2019; Weismann

et al., 2019). The *baggāras* in particular are extremely rare. They are the first sewn versions of this type of vessel known to academia—it was previously recorded only as a nailed vessel—and are probably the only predominantly sewn boats from within the Gulf held in any museum. They complement four sewn *kambārīs* held by museums in Oman as representative of the wider sewn tradition of Arabia (Weismann *et al.*, 2019). In one respect—the attaching of both port and starboard garboard strakes to the keel in a single, continuous stitching process—*baggāras* are unique in the scholarly record.

The rarity and importance of the *baggāras* is augmented by the extensive presence of bitumen on the hulls, applied as a waterproofing, anti-fouling, and otherwise protective coating. While the use of bitumen on seagoing and river craft is attested in the region from ancient times (Cleuziou and Tosi, 1994; Potts, 1995; Vosmer, 1996; Carter, 2002), its recent use on plank-built vessels—whether in the region’s sewn or clenched-nail traditions—remains little examined.

We apply common English usage in referring to vessels with timbers bound together by continuous cordage as ‘sewn’. This closely reflects Arabic, where the root kh-y-ṭ (خيط) denotes the action of joining (i.e. sewing) both textiles and boat timbers (Wehr, 1976: 267–268; Agius, 2008: 161–168; al-Salimi and Staples, 2019: 63–65). It less effectively reflects Malayalam, where the term *kettuvallam* means ‘tied (or bound) boat’, the action *kettuka*, meaning ‘tying’ (Ransley, 2009: 5 (§5), 18; 2012: 247–248) or ‘binding tight’ (Gundert, 2013 (1872): 205).

Research goals

This article is the outcome of fieldwork that had as its primary objective the detailed documentation of QM’s sewn watercraft for the first time. The principal visual outputs—construction drawings, naval-lines drawings, and 3D digital models based on photogrammetry—are presented (Figs 1–7; see also supplementary materials). The fieldwork further sought to understand the processes and techniques deployed in building the craft, as well as the variety occurring among them. A further objective—to be addressed in a separate publication—was to compare the use of bitumen on the hulls of the *baggāras* with fragments recently found at Fuwairit in north-eastern Qatar by an archaeological team from University College London-Qatar led by Robert Carter: these may relate to nautical activity (Carter, pers. comm., 23 November 2019).

Methodology

QM kindly granted access to the vessels at its Dhow Section in Doha in April 2019, preparing and positioning the boats for survey. The authors undertook a programme of 3D photogrammetric survey and close visual inspection of the QM vessels.

3D photogrammetry

The authors carried out three photogrammetric surveys per boat using a different camera each time: a Nikon D310 digital SLR, a Sony Cyber-shot DSC-RX100 II compact camera, and a GoPro Hero 3+ action camera. The triplication enabled comparison of the data obtained across the devices and selection of the best for the intended use, as well as mitigating against camera failure.

The two-stage process began with the team taking series of overlapping photographs of each vessel from a relatively fixed distance in a sequence of orbits around the boat. The limited space between the vessels necessitated the use of wide-angle lenses (Tamron 10–24 mm, 1:3.5–4.5 on the Nikon camera); the Metashape Pro photogrammetry software¹ is capable of correcting the resulting distortion (Fiorillo *et al.*, 2016: 69–70). The authors took as many as 767 photographs gathering their first set of photographs, for *baggāra* 1, but later reduced this to 418 for the *kettuvallam*. The second stage involved processing the photographs in Metashape Pro, which generates 3D point clouds from the still images (Yamafune *et al.*, 2017: 3). The files produced can be scaled and measured with a high degree of accuracy (cf Martorelli *et al.*, 2014: 91).

Construction drawings

The authors reverse-engineered conventional construction drawings from the photogrammetry models. Screenshots were taken of orthographic views of the plan, profile, bow, and stern of the 3D models, plus a longitudinal and three lateral cross-sections. These were then imported into one or other vector-drawing software programs (Affinity Designer for Cooper’s drawings; VectorWorks for Ghidoni’s; Autocad for Zazzaro’s), and the visible structure traced. Areas of blinding, especially under the fore and quarter decks, presented a challenge to tracing, as did the dark bitumen colour: these were mitigated by continued reference to still photographs and field notes. The final drawings are presented in Figures 1–4. The principal dimensions and ratios, plus comparisons with other western Indian Ocean sewn craft are presented in Table 1.

Naval-lines drawings

The conventions of naval-lines drawings rest on the presumption of a longitudinal reflectional symmetry in the hull that few vernacular vessels have in reality: modelling the buttock and half-breadth lines of only one side of the hull, following convention, would therefore generate a misleading representation of moulded form. Meanwhile, the 3D mesh models that were generated through the photogrammetry process provide the necessary basis for any future hydrodynamic modelling of the actual hulls. Instead, the authors generated ‘edge-shaped’ lines drawings for the *baggāras*, presenting an idealized representation of

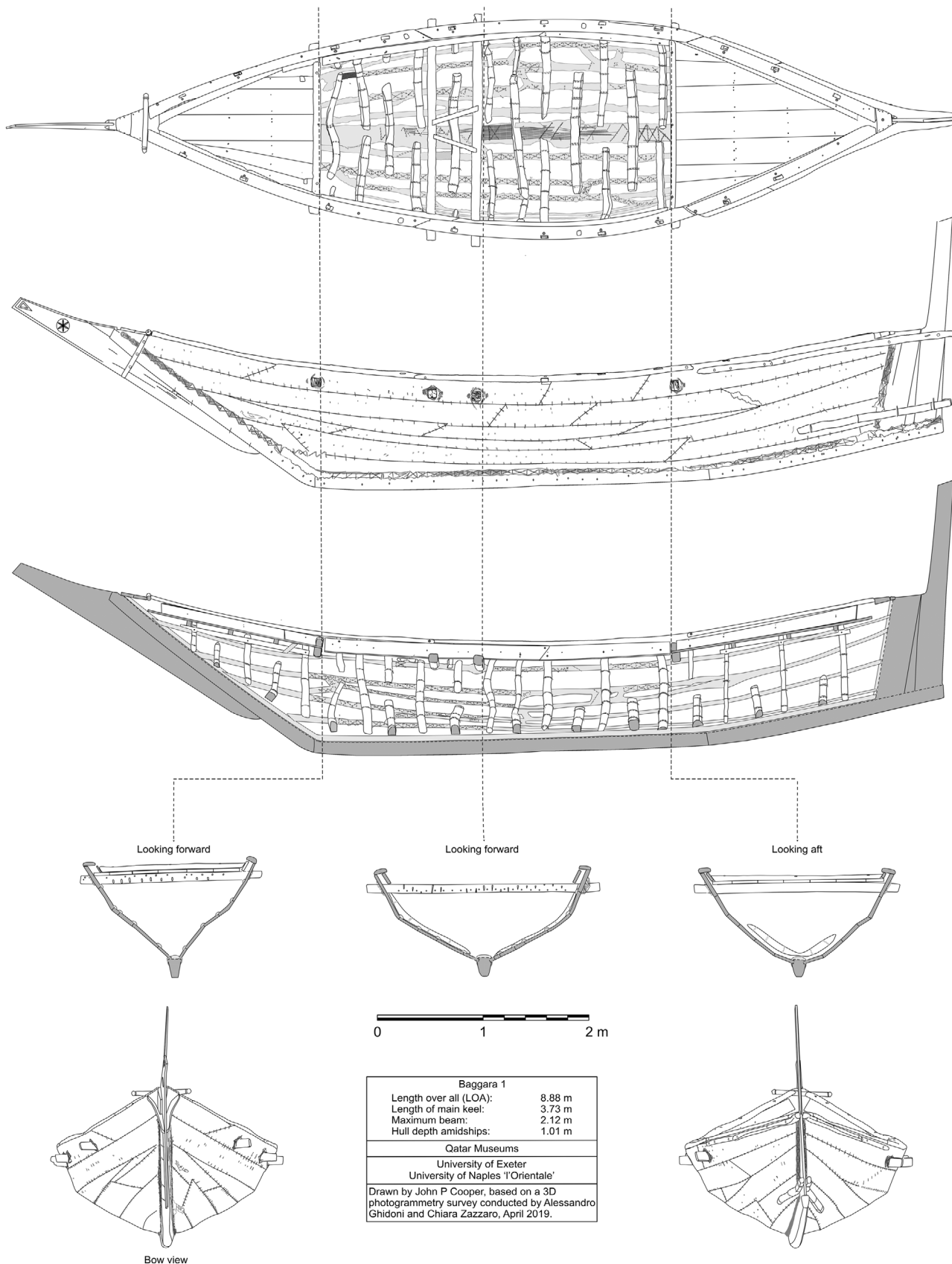


Figure 1. Construction drawing of *baggara* 1. (Image: John P. Cooper).

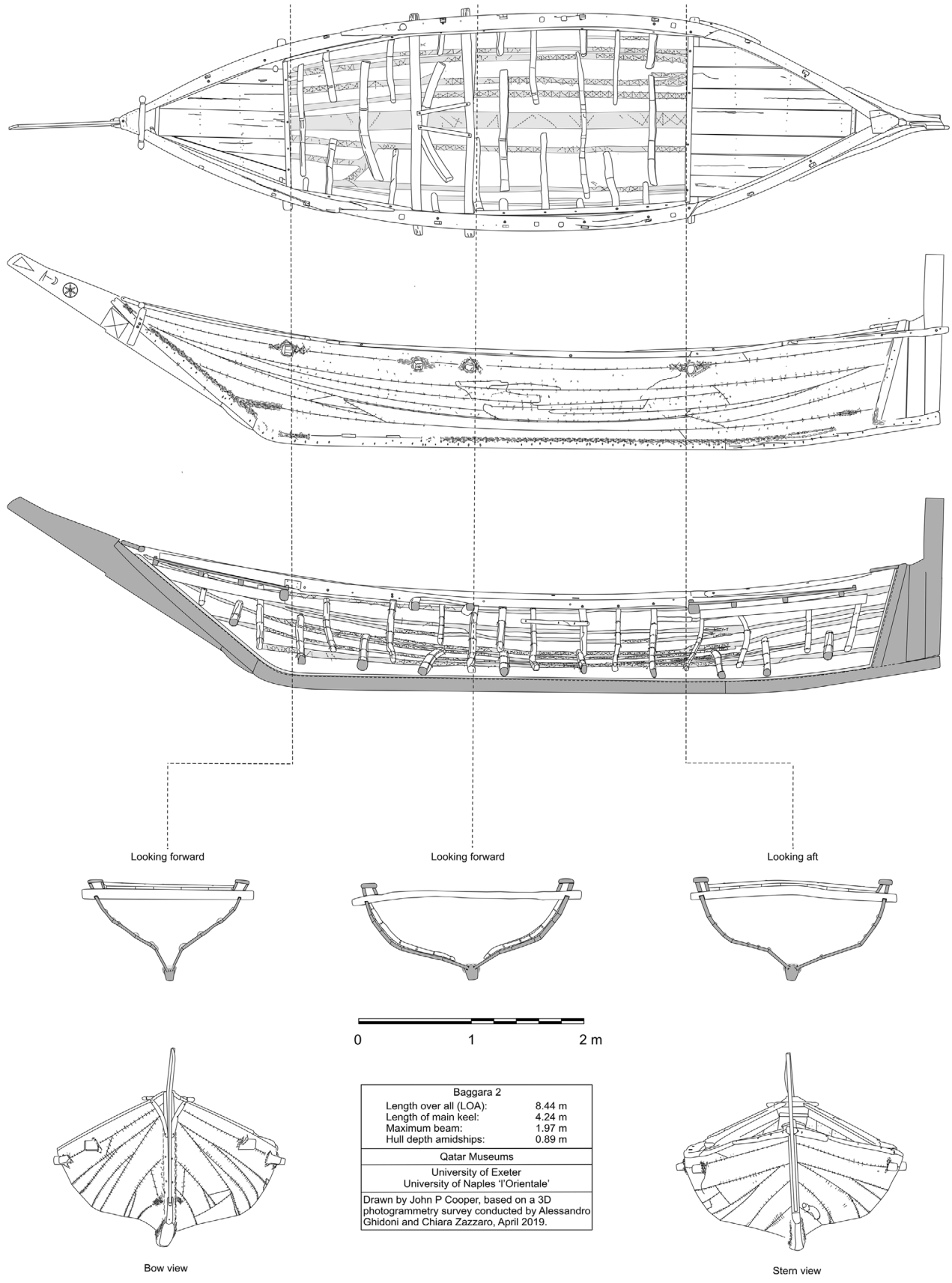


Figure 2. Construction drawing of *baggara 2*. (Image: John P. Cooper).

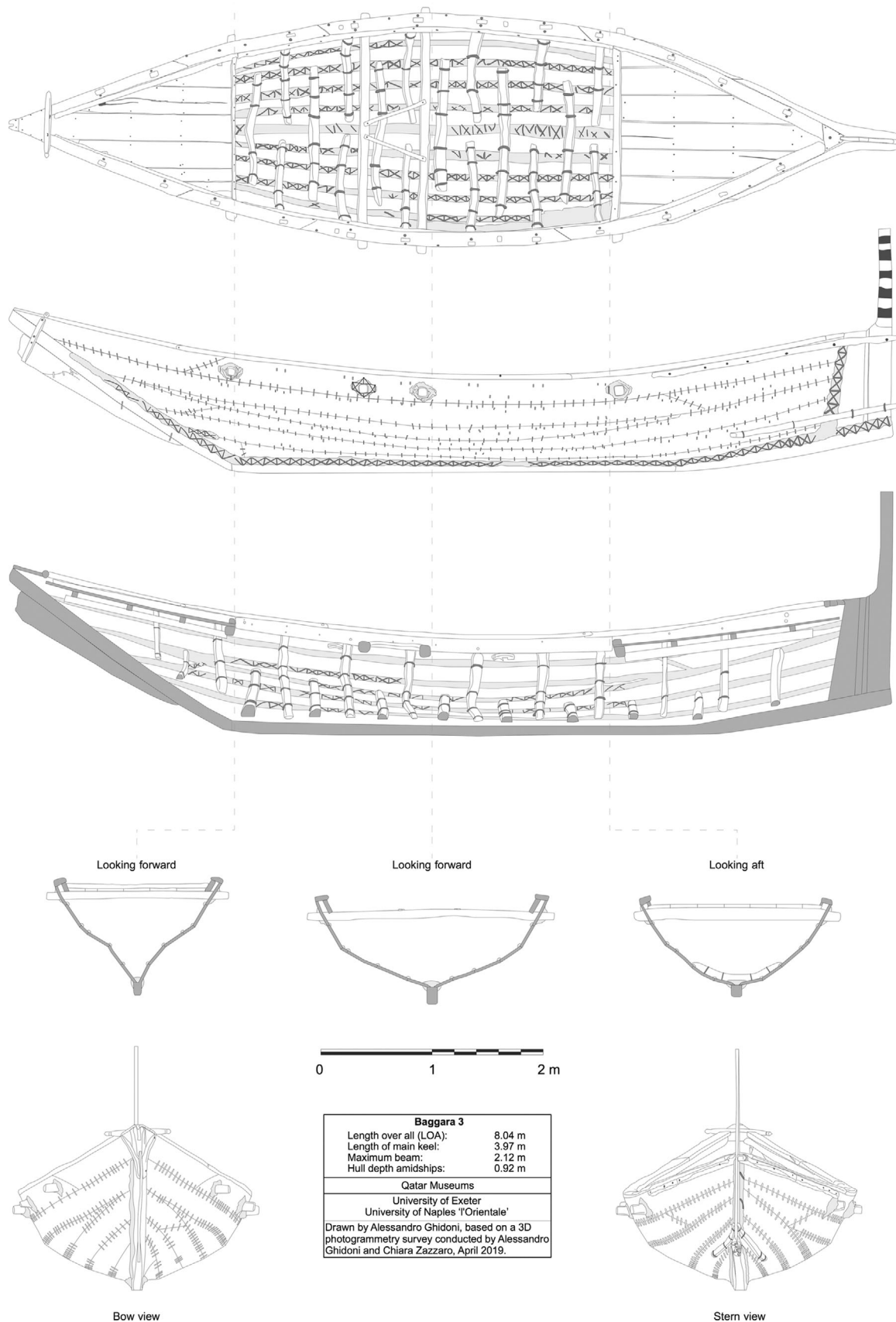


Figure 3. Construction drawing of *baggāra* 3. (Image: Alessandro Ghidoni).

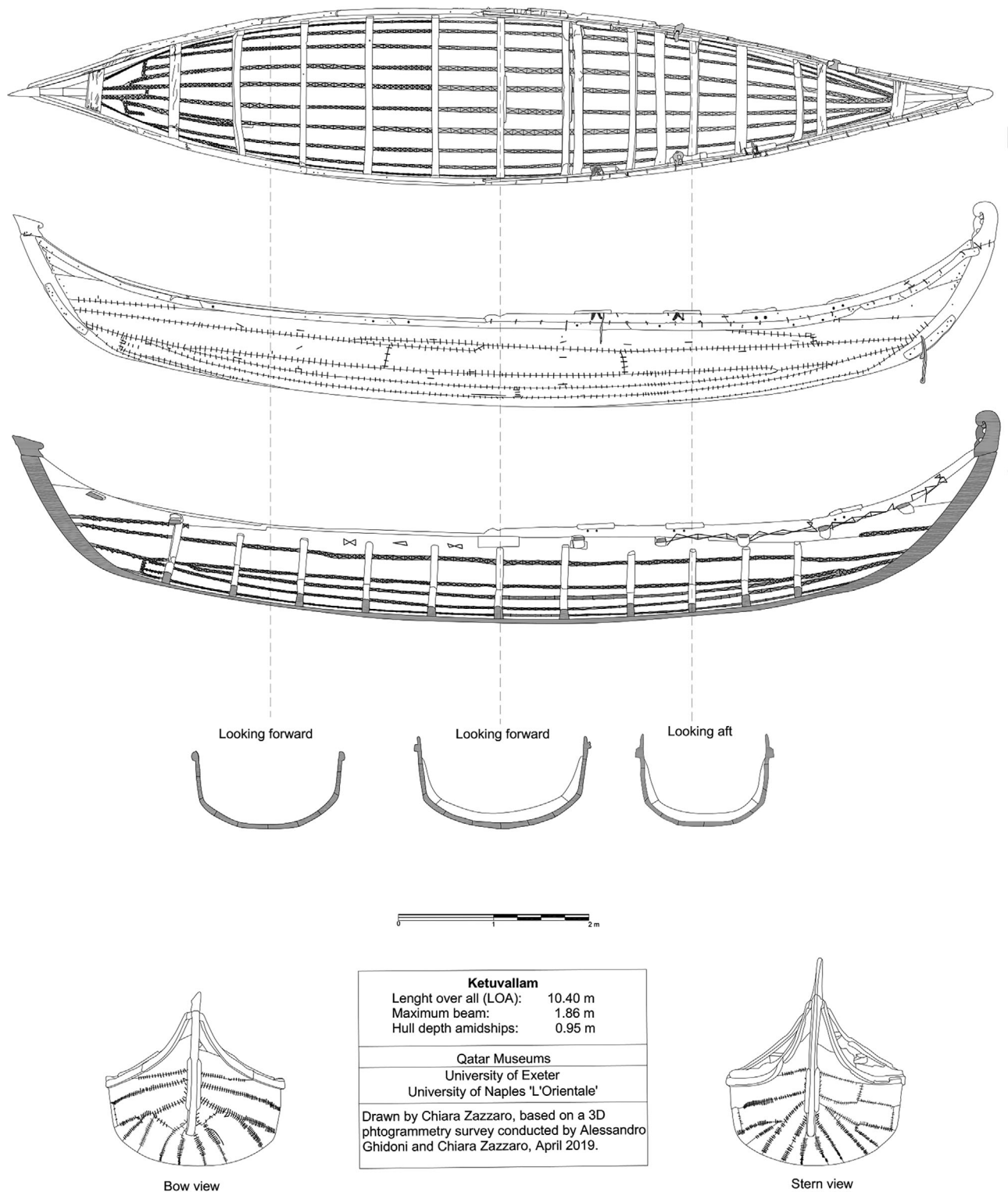


Figure 4. Construction drawing of *kettuvallam* B. (Image: Chiara Zazzaro).

the hull that is nevertheless extrapolated from actual dimensions: essentially, any mutual deviations in port-starboard symmetry were mathematically ‘smoothed out’ (Figs 5A-B and 6A). This approach preserves

the particular polyhedral geometry of the hull, and can be seen as presenting the underlying ‘archetypal’ concept of the hull, while at the same time excluding irregularities introduced in the execution of the build

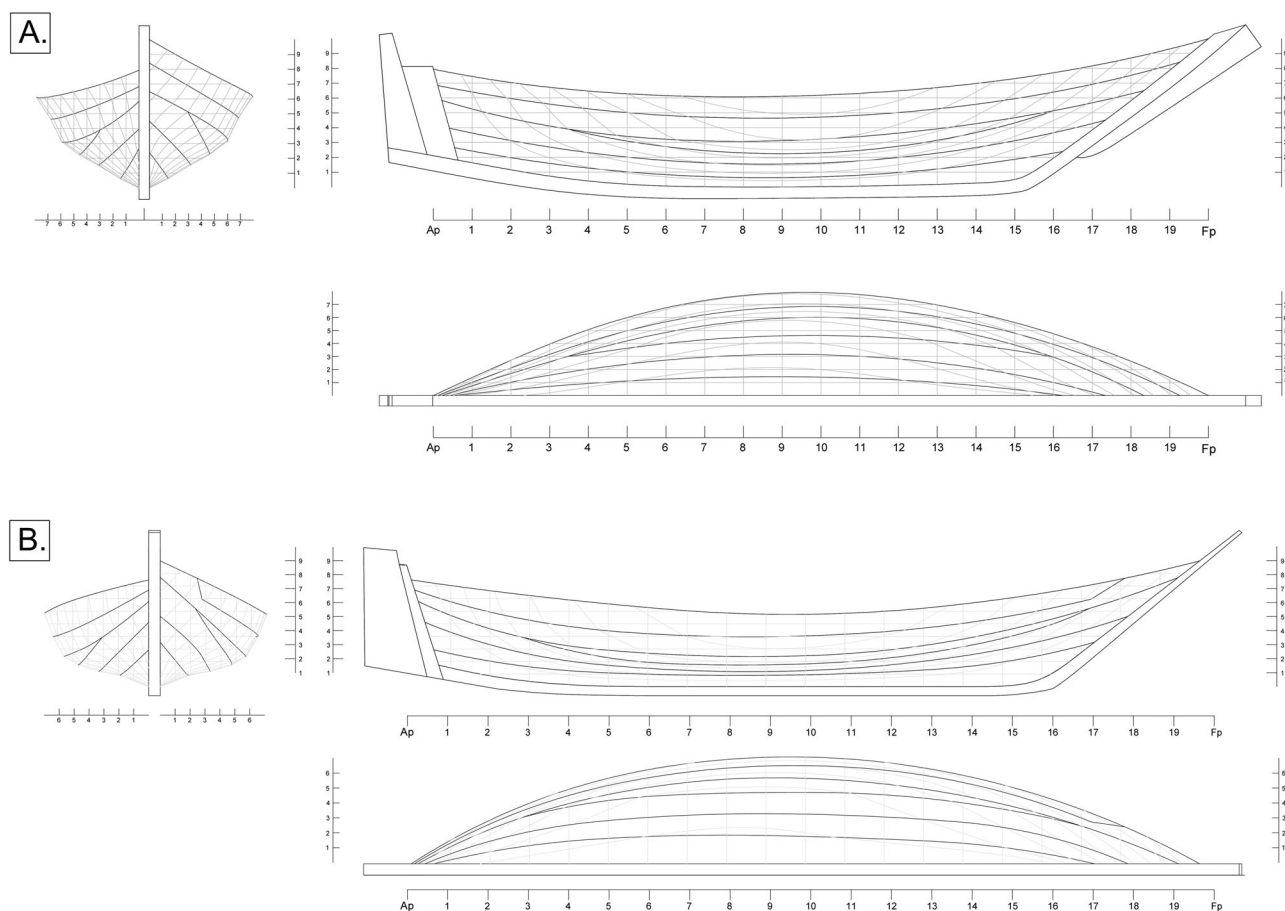


Figure 5. Naval-lines drawings of: A) *baggāra* 1; and B) *baggāra* 2. (Images: Luigi Ombrato).

(Ombrato *et al.*, 2020). For example, the builder of *baggāra* 3 has inserted a small triangular plank towards the bow in order to achieve the desired degree of curvature.

The lines drawings were produced initially by creating actual curves from the mesh models generated from the 3D photogrammetry. The mesh was divided into eight equal parts and sliced to produce seven each of half-breadth lines, buttocks, and waterlines. As expected, the resulting lines proved highly asymmetrical. In order to obtain the final ‘edge-shaped’ representation, the principal ‘edges’—angles found along the planking seams of the hull—were traced onto the mesh model, before starting the slicing. The curvatures of each side were then mirrored, overlapped, and mediated with the curve on the opposite side, and the final edge-shaped hull lines created. Because the drawings simply mediate the asymmetries, they remain a valid basis for generating moulds in any reconstruction scenario.

The less faceted and more symmetrical hull of the *kettuvallam* allowed the authors to produce only the conventional form of naval-lines drawing (Fig. 6B).

Provenience and context

Little is known of the provenience of the sewn *baggāras*, except that QM acquired them in Hormuzgan province, southern Iran, in 2013. Whether sewn or nailed, vessels known by this name were in the previous century found on both sides of the Gulf and in the Gulf of Oman between Musandam and the northern Batinah coast (Lorimer, 1915: 2323; Howarth, 1977: 46; Shihāb, 1987: 53; Vosmer, 1997: 219; al-Hijji, 2001: 11–12; Weismann *et al.*, 2014: 418). An 1898 model of what appears to be a large sewn *baggāra* from the Horniman Museum, London bears a label saying it operated throughout the Gulf.²

Agius (2002: 106–107) traces the word *baggāra* through text as far as the 18th century CE, and suggests the term might be Persian—although al-Salimi and Staples (2019: 48–49) argue it might relate to the Arabic word *baqara* (بَقْرَة), meaning ‘cow’, given the vessel’s somewhat bovine stem-head. In any case, textual mentions are problematic because they might refer to a variety of vessel types and construction methods. Native speakers apply the term to indicate the vessels described here or a range of similar, predominantly nailed, boats from south-eastern Arabia—the already

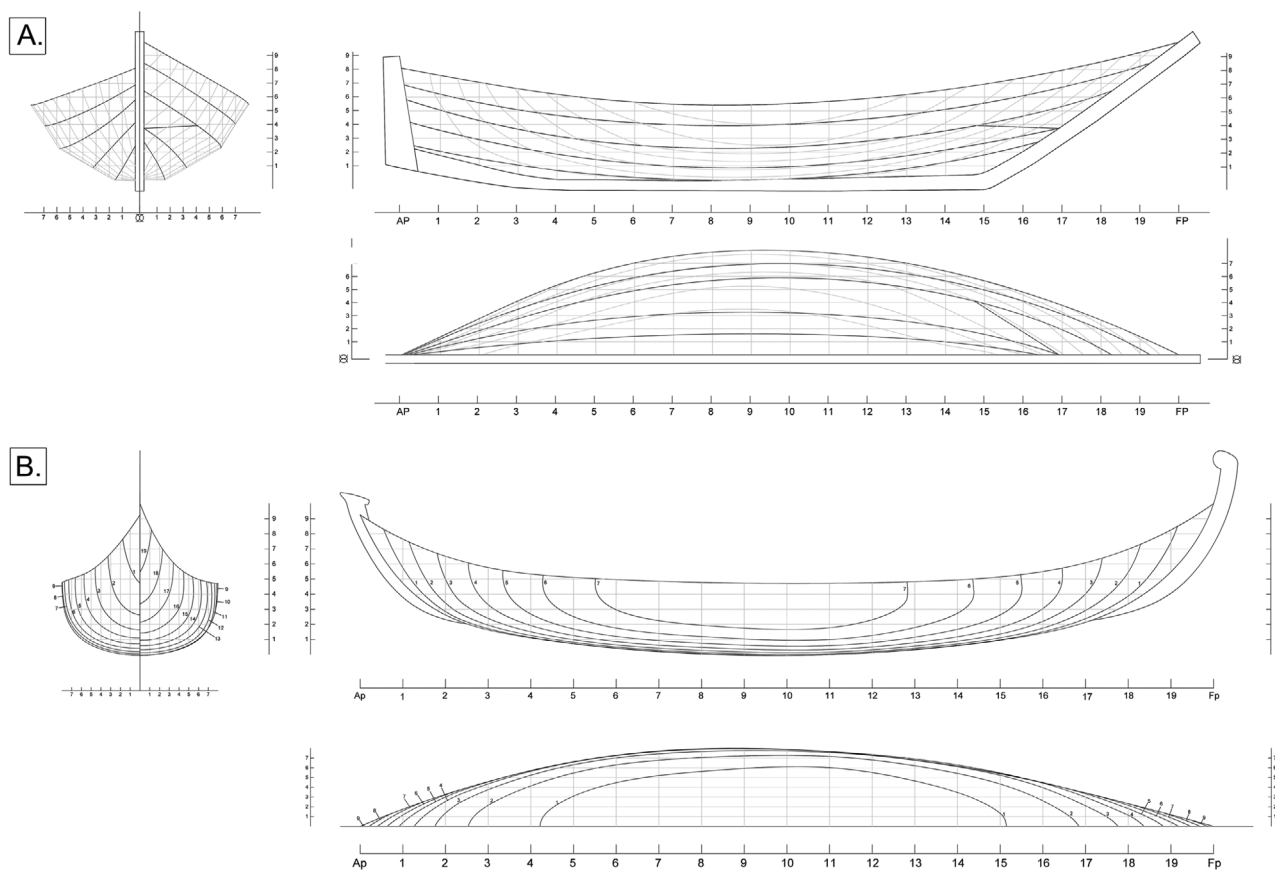


Figure 6. Naval-lines drawings of: A) *baggāra* 3; and B) *kettuvallam* B. (Images: Luigi Ombrato).

mentioned ‘Emirati *baqqārah*’, the *shāhūf* (شاهوف), *zārūqa* (زاروقة), and *battīl* (بتيل), which vary in length from 4.5–20 m (Lorimer, 1915: 2323; Howarth, 1977: 45–47; Facey, 1979: 142; Shihāb, 1987: 113–117; Vosmer, 1997: 219–230; al-Hijji, 2001: 13; Agius, 2002: 105; Weismann, 2005; Weismann *et al.*, 2014). These have in common a double-ended hull, straight, raking stem, stern fin (*fashīn*) and angled, two-part keel with a rocker aft (Vosmer, 2005: 306). Some, such as the Omani *battīl* and *badan*, had their stem and stern posts sewn (Facey, 1979: 144; Shihāb, 1987: 53; Agius, 2002: 111), perhaps as an intermediate stage in a sewn-to-nailed transition. The QM *baggārās* have strong similarities to the Omani *zārūqa* and *battīl*: *fashīn* shape and hull profile resemble those of the former, while their size and sewn through-beams resemble the latter.

In the Qatar and the United Arab Emirates, and more generally in the southern and western shores of the Gulf, smaller *baggārās*—such as those in the QM collection—were used for coastal fishing, and were generally rowed. The larger versions (cf Fig. 8) were used for pearling and carrying cargo, and had one or two masts and a crew of 15–30 (Lorimer, 1915: 2323). In Oman, the *baggāra* of the mid to late 20th century was a medium-sized vessel of nailed construction, ranging in length 25–35 ft (7.6–10.7 m) used for fishing

and cargo (Facey, 1979: 143; Agius, 2002: 105). Its geographical distribution—between that of the *battīl* of Musandam to the north and the *badan* of the coast of southern Batinah and Muscat to the south—is reflected in commonalities in shape and construction with both these vessels (Vosmer, 1997: 230).

Iconographic evidence for *baggāra*-like vessels is limited. The *gharookuh* illustrated by Pâris while visiting Muscat in 1839 (1841: 13–14, Plate 5), is among the earliest: he says it occurred in the Gulf and travelled as far as Kerala. It has features common to both the *baggāra* and *battīl*, such as the raking bow, *fashīn*, and angled keel; however, the stem-head makes it closer to the former. Although the Horniman Museum model is labelled only as an ‘Arab Vessel’, Weismann (unpublished report 2005) identifies it as a *baggāra* on the basis of the stem-head, even though its *fashīn* resembles that of a *battīl*. Evidence for the existence of *baggāra*-like vessels in Qatar itself comes from the rock carvings of vessels in profile at Jabal Jusasiyah in the north-west of the peninsula (Kapel, 1983: 53–55, fig. 9–11; Facey, 1987: 200–201, 211, fig. 4). These have been recently dated to 235 years before present (Hassiba *et al.*, 2012: 13).

QM acquired the *kettuvallams* in 2012 from a private individual, the only provenience being that they came



Figure 7. Photogrammetry models of: A–C) *baggāras* 1–3; and D) *kettuvallam* B. (See also supplementary information. Images: Alessandro Ghidoni and Chiara Zazzaro).

Table 1. Principal dimensions and ratios of the Qatar Museums sewn boats, with comparisons to other published sewn watercraft of the Western Indian Ocean

Vessel	Dimensions (m)				Ratios	
	Length over all	Length of hull	Max. Beam	Min. Depth	length: beam	beam: depth
QM vessels						
<i>Baggāra</i> 1	8.88	7.45	2.12	1.01	3.5	2.0
<i>Baggāra</i> 2	8.44	7.00	1.97	0.89	3.6	2.2
<i>Baggāra</i> 3	8.04	7.44	2.12	0.93	3.5	2.3
<i>Kettuvallam</i> A (based on 2013 survey)	n/a	10.08	1.86	0.99	5.4	1.9
<i>Kettuvallam</i> B	10.55	10.16	1.77	1.00	6.0	1.8
Comparators						
Indian <i>masula</i> (Kentley, 1985: 305)	7.5–8	7.5–8	n/a	n/a	3.5	2
Yemeni <i>sanbūq</i> (Prados, 1996: 109)	6.85	6.85	1.30	0.62	5.3	2.1
Omani <i>kambārī</i> (MFL) (Weismann, 2019: 351)	10.29	10.29	1.99	0.95	5.2	2.10
Omani <i>kambārī</i> (Sur 1) (Weismann, 2019: 351)	11.30	11.30	2.30	n/a	4.9	n/a
Omani <i>kambārī</i> (Sur 2) (Weismann, 2019: 351)	11.77	11.77	2.40	n/a	4.9	n/a
Somali <i>beden</i> (Chittick, 1980: 299)	10	10	1.82	n/a	5.5	n/a

from Kerala. Photographic evidence suggests that they are amphidromous. There is a dearth of published literature on Keralite sewn vessels, despite it being one of the last strongholds of sewn construction in the Indian Ocean. Rajamanickam's study of Indian

watercraft (2004: 68–71, 102) lists a number of 'stitched plank-built boat[s] without keel' in Kerala, but the QM boats correlate to none of them precisely. Other, earlier studies on Indian watercraft, such as by Edye (1834), Pâris (1841), and Hornell (1920, 1946) focus



Figure 8. Large *baggāras* on the beach at Doha, Qatar, in 1904. (Image: Hermann Burchardt).

on vessels from other Indian regions, while Hornell states—incorrectly—that vessels from Kerala can be divided into dugouts and planked ‘pseudo-dugouts’, remarking (bizarrely) for the latter that ‘there is so little variation ... that there is almost nothing to say of them’ (1920: 150). What little recent research there has focused on riverine vessels, such as those of the backwaters around Alleppey (Ransley, 2009), or sewn boats from neighbouring regions (Kentley, 1985; 2003a; 2003b; Shaikh *et al.*, 2011; Fenwick, 2015; Shaikh, 2019).

Rajamanickam’s description of what he calls a *kettuvallam* (2004: 68–69) bears some similarity to the QM vessels: both are double-ended and sewn, with a crescent-shaped profile and U-shaped cross-section. Neither have a proper keel: the flat, central ‘keel plank’ has the same thickness as the rest of the hull. The stems and sterns of both vessels are fastened only to the top strakes. Rajamanickam says his *kettuvallam* can measure up to 20 m in length, while only 1.35 m wide and 0.9 m deep at midships. Frames, spaced around 1 m apart, give the hull structural strength, as do a series of thwart. Rajamanickam provides only one small photograph and a lines plan to illustrate his *kettuvallam* (2004: 70, fig. 11, 116, pl. 19). Unfortunately, his photograph gives limited information and the purported lines drawing is of an entirely different vessel. This lack of information makes our identification of the *kettuvallams* by that name tentative. The term is generic for a vessel fastened with cordage (Ransley, 2009: 18; 2010: 429). Early Tamil and more recent Malayalam works of literature mention also the term but provide no details of form (Greeshmalatha, 2013: 33; Rajamanickam, 2004: 64).

Keralite fishermen use the *kettuvallam* for coastal fishing. They launch through the surf and propel the vessel with oars, steering with a paddle (Hornell, 1920: 150; Rajamanickam, 2004: 69).

Patrice Pomey briefly describes *kettuvallams* in two articles (2012; 2011: 138–139) and in a documentary

film (Pomey and Raymond, 2012: minute 08.30). His interest in these boats is primarily directed at their sewing technique, which is very similar to that of Greek archaic sewn boats found in Marseille, France (Pomey, 2012: 126–127, fig. 17). In both articles Pomey states that *kettuvallam* are from the Malabar coast and identical in technique to those of the Lakshadweep islands. The documentary provides unique evidence of maintenance and construction tools.

Condition of the vessels

The QM *baggāras* are in varying states of repair (Fig. 8). The three presented in this article have a high degree of structural integrity, but show deterioration around key areas of stitching, in particular along internal and external portions of their garboard-keel jointing, and also at their posts. Plank stitching and its wadding is also worn internally in areas of greatest traffic.³ *Baggāra* 3’s prow timber—the term we use to designate the carved, decorated, and possibly sacrificial timber that establishes the vessel’s bow profile—is broken off (Fig. 3). *Baggāra* 1 showed signs of dry rot on some planking.

The two *baggāras* not discussed in this paper are in significantly poorer condition. These were wrapped in geotextile at the time of the survey, and the authors did not inspect them in detail: however, their keels were visibly weakened by past infestations of marine boring organisms.

The two Indian *kettuvallams*, meanwhile, are in a robust state.⁴ The timbers are largely intact and show no signs of deterioration beyond general wear; the stitching and wadding remain in place and tight throughout.

Construction sequence

The QM sewn boats are built according to variants of a shell-conceived system of sewing and lashing

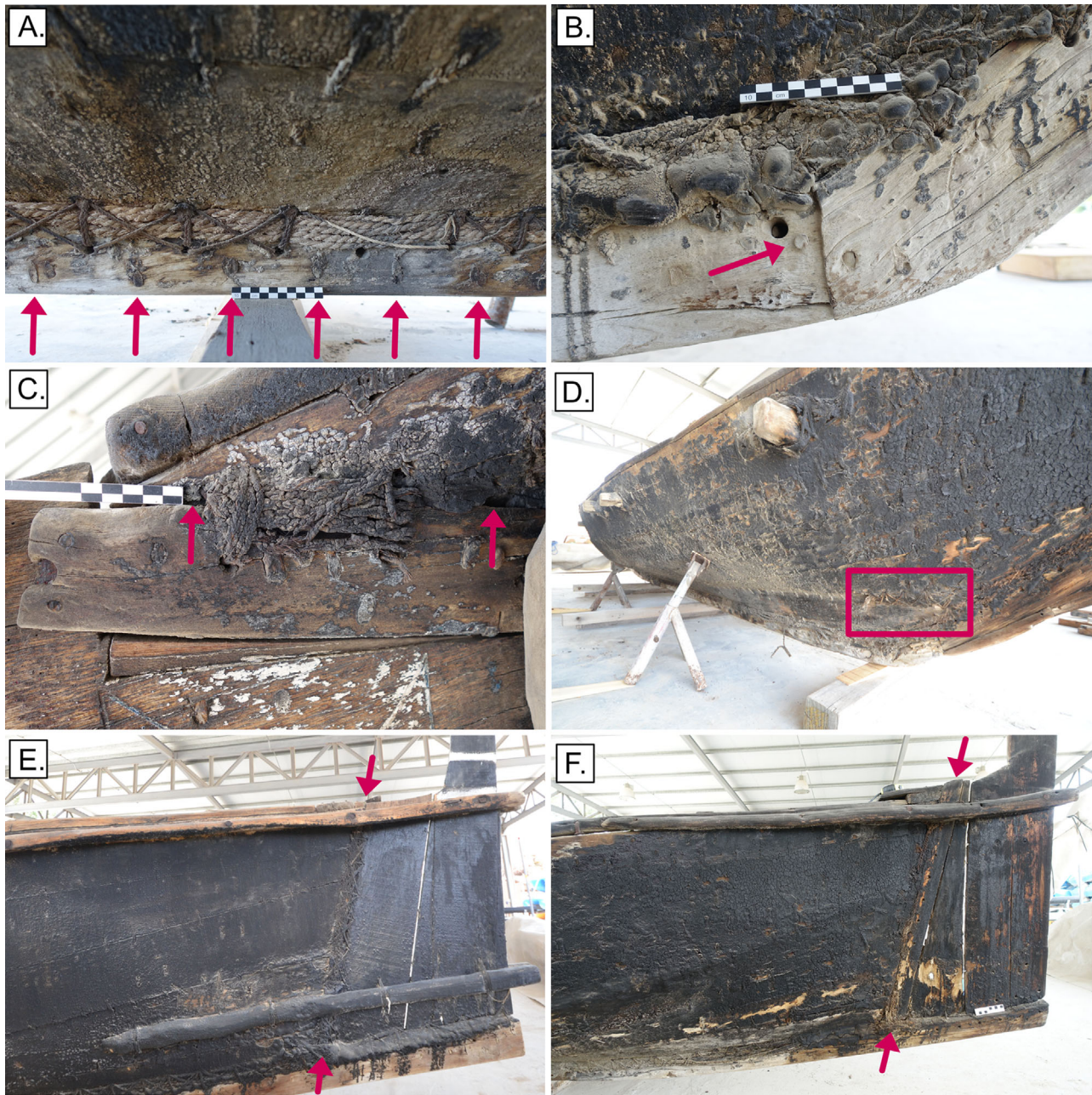


Figure 9. Construction features of the keels and posts of the QM *baggāras*: A) oblique dowels in the keel of *baggāra* 2, fixing the garboard strake; B) the jointing of the keel to the 'false' outer stem of *baggāra* 1, with perpendicular dowel suggesting the locking of inner jointing; C) rabbeting of the outer stem of *baggāra* 2 around the hood-ends; D) a short run of [X|X|X] stitching on the outboard hull of *baggāra* 2, related to the stitching of the 'false' outer stem; E) stitching of the hood-ends of *baggāra* 1 direct to the first plank of the *fashūn*; F) stitching of the hood-ends of *baggāra* 2 to a dedicated sternpost timber: the stitching has been removed. (Images: John P. Cooper, Alessandro Ghidoni, Chiara Zazzaro).

that is one of two principal western Indian Ocean boatbuilding traditions—the other being the clenched-nail system (Hourani, 1995 (1951): 92–97; Yajima, 1976: 25–27; Howarth, 1977: 20; Shihāb, 1987: 41–112; al-Hijji, 2001: 44–76; Agius, 2002: 143–145). In the sewn tradition, hull planking is joined by continuous stitching along a flush seam, usually leaving a [X|X|X] pattern inboard, with plugged holes. In the Arabian

tradition—and, on the evidence of the *baggāras*, the Iranian—the planking is aligned using wooden dowels fixed into the faying surfaces (Bowen, 1952: 220–221; Prins, 1986: 87–89, 100–109; Prados, 1996: 101; Vosmer, 1997: 233–234; Weismann *et al.*, 2019: 354–356). Many Indian and Sri Lankan sewn boats do not have dowels (Kentley, 2003a, 142; 2003b, 174–175; Fenwick, 2015, 393; 2019: 389); builders sometimes

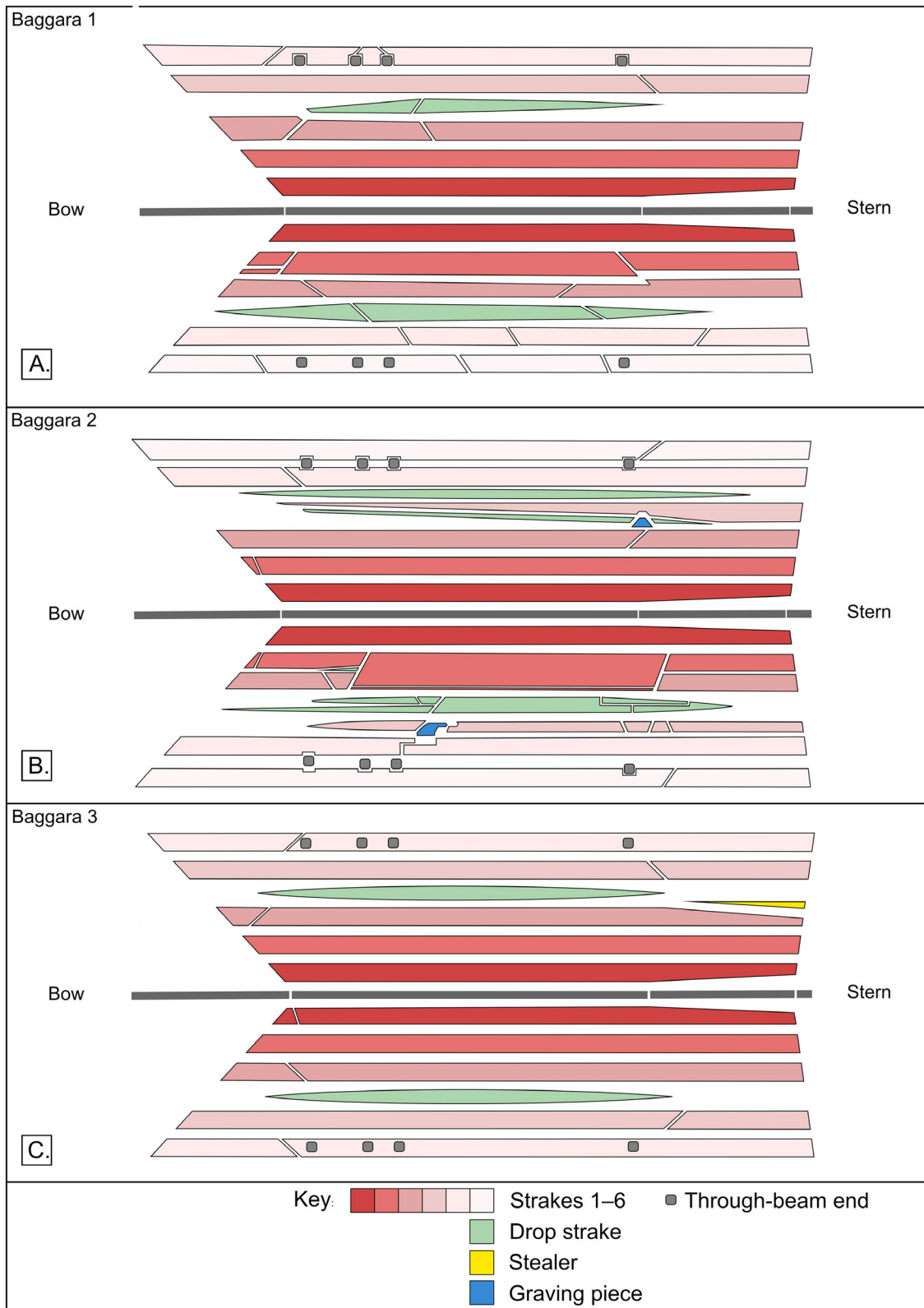


Figure 10. Schematic planking plans for QM *baggāras* 1–3. Not to scale. (Image: John P. Cooper).

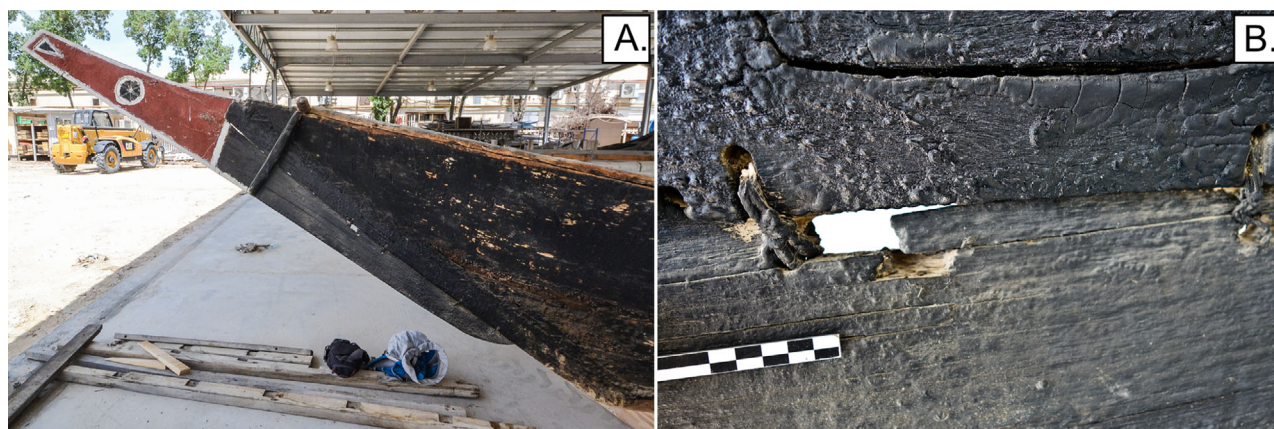


Figure 11. A) The prow timber on QM *baggāra* 1; B) detail of its widely spaced lashings. (Images: Alessandro Ghidoni and Chiara Zazzaro).

make use of plank edge-grooves instead (Shaikh *et al.* 2011: 152).⁵ The 8th-century-CE Phanom-Surin and 9th-century-CE Belitung wrecks also have no dowels visible in their hull planking (Abhirada Komoot, pers. comm. 29 April 2020; Flecker, 2000: 200), although the Phanom-Surin wreck has not yet been fully investigated.

Outboard, the planking stitches on the QM vessels are set into vertical rebates between the stitch holes, creating a |||| pattern; inboard, the stitching is over a continuous pad of wadding; this is vegetal in the *baggāras*, and in the Indian *kettuvallams* is composed of a fine netting of unknown material. Framing timbers are fixed with lashings in both vessel types.

Baggāra construction

The inferred construction sequence of the *baggāra* is as follows.

Keel and posts

The construction process begins with the builders laying a keel comprising two end-butted timbers with a broadly U-shaped or rounded-trapezoidal cross-section, similar to the sewn *kambārī* in the Museum of the Frankincense Land, Oman (Weismann *et al.*, 2019: 349), the Goan *revenchem vodem* (Shaikh *et al.*, 2011: 151) or East African *mtepe* (Prins, 1986: 84). The keel's longer forward timber represents about two-thirds of the total keel length⁶ and has an upward-curving forefoot that joins an outer ('false') stem. The keel's shorter aft timber rakes upward—at 12° on *baggāra* 1, and at 10° on *baggāras* 2 and 3—and is slightly curved at its forward end (Figs 1–3). The internal joinery of these two vital timbers is unknown. It is improbable they are simply end-butted, given the forces in play during both construction and life of the *baggāra*, but there is no indication of any internal joinery visible externally.

Likewise, the presence of stitching and wadding inboard and outboard along the keel's length—together with the *in situ* garboards—made it impossible to ascertain whether the builder of the

QM *baggāras* rabbeted the keel to receive the garboard strakes, something common in regional clench-nailed boatbuilding (Millward, 1951: 198–199; Hawkins, 1977: 102; Howarth, 1977: 63; Facey, 1979: 158; al-Hijji, 2001: 44–49; Agius, 2002: 150–153) and also seen on the sewn *battil* and at least some Omani *kambārīs* (Vosmer, 1997: 224; 2005: 332; 2019: 309), the Yemeni sewn *sanbūq* (Prados, 1996: 100), and the Goan *revenchem vodem* (Zeeshan Shaikh, pers. comm., 19 October 2019). The fact that a portion of the upper face of the *baggāra*'s keel steps outwards suggests unseen rabbets (Weismann *et al.*, 2019: 350). An alternative explanation might be that the builders carved longitudinal lugs along the keel's upper face to prevent the garboard strakes from slipping inward, an approach adopted by the builders of the Belitung wreck (Flecker, 2000: 202), but with no recent ethnographic parallel.

The existence of these steps rules out the possibility that the QM *baggāras*' garboard strakes are simply butted against a bevelled upper corner of the keel. Weismann *et al.* (2019: 350) infer that bevelling is 'probably' the configuration on the four museum-held *kambārīs* in Oman. However, they note (2019: 343–344) that the two *kambārīs* on display at the Fatah al-Khair Centre in Sur, Oman, were all built by the same builder for museum display, rather than as working boats. Weismann suggests this might be a factor in their divergence from *kambārīs* observed ethnographically (pers. comm., 24 October 2019).

Another feature of the garboard-keel jointing in the QM *baggāras* is the sequence of obliquely cut wooden dowel heads apparent along the length of the keel—at the rate of one per keel-garboard stitch (Fig. 9A). One function would have been to hold the shaped garboards in place in readiness for stitching, but their close spacing suggests a long-term fixing role. By measuring the ends of the dowels cut flush with the keel's moulded faces, it is possible to infer their angle of insertion and calculate their paths through the keel. Amidships, for example, the dowels of *baggāra* 3 form angles of between 33° and 40° with the keel's moulded side. This angle deviates too

much from the vertical to allow it to fasten the garboard on the *same* side of the hull: rather, it suggests that the builders of the *baggāras* drove the dowels diagonally through the lower edge of one garboard and through the keel, emerging on the keel's opposite moulded face.

The use of dowels to align and anchor the garboard is also seen on the working *kambārī* from Taqa in the Oman Across the Ages Museum (OAAM) in Manah, Oman (Weismann, pers. comm., 24 October 2019). Professor Dionisius A. Agius of the University of Exeter also showed the authors a photograph he took of a *kambārī* in Taqa in 1996 that also shows such dowels.

The builders of QM *baggāras* 1 and 2 set the stem at around 38° to the keel, while that of *baggāra* 3 was set at a more raking 35°. The nature of the joinery fastening the keel to the stem posts—the 'false' outer one and, where present, the inner one—is again unknown due to its concealment. However, at least some use of oblique dowels is evident on the joinery of the false outer stem to the keel on *baggāra* 2—including, apparently, some pegged dowelling (whether intentional or coincidental). The visible heads of horizontal dowels driven perpendicularly into the keel alongside this joint on *baggāra* 1 also suggest these are acting as locks to an unseen internal joint (Fig. 9B). In comparison, Flecker (2000: 201–202) reports a lightweight mortice and tenon arrangement in the keel-to-stem joinery of the Belitung wreck, which he suggests was for initial alignment rather than structural strength. In the sewn *revenchem vodem* of Goa, meanwhile, the stem is obliquely stop-tenon-jointed into the keel before the planking is laid: the joint is also locked, using a 'small wooden block' (Shaikh *et al.*, 2011: 151).

A parallel for the construction of the *baggāra* bow section may be Vosmer's interpretation (1997: 229) of the sewing-on of the false outer stem of the otherwise-nailed Omani *battīl*, the hood-ends of which are sewn together before the post is affixed. In the case of QM *baggāra* 2, the hood-ends appear to have been brought together around a fine internal stem of trapezoidal cross-section. No comparable internal stem was visible on *baggāras* 1 and 3, although these might have been concealed beneath stitching and wadding. By analogy with Vosmer's *battīl* interpretation, it would have been after the stitching together of the hood-ends that the false outer stem was affixed to the bow: by means of a second run of stitching. Prados (1996: 103) also observed the practice of attaching the outer stem after the stitching together of the hood-ends in the Yemeni sewn *sanbūq*. Meanwhile, Chittick (1980: 299–300) notes that the Somali builders of the *beden* added the stem and stern posts after the third strake had been fixed. On *baggāra* 2, the false outer stem is rabbeted at its upper end to accommodate the hood-ends, but lower down it is simply butted (Fig. 9C).

A further corroboration of the *battīl* analogy is the presence on all three of the QM *baggāras* of a short run

of outboard stitching running back from the stem for about 0.30 m along the seam between the garboard and second strakes (Fig. 9D). Vosmer (1997: 229) observed this same feature on the false stem on the otherwise-nailed Omani *battīl*. This is unlike the approach taken by builders of the Indian *masula*, who join the stem and stern posts and hood-ends together in a single sewing action (Kentley, 1985: 307).

The lack of visibility of the internal jointing again hampered interpretation of the builders' approach(es) to bringing the hull planking together at the stern. In *baggāra* 1, and probably also 3, the builders butted the hood-ends directly against the forward moulded face of the first plank of the *fashīn*—the upright 'fin' at the stern—and stitched this assemblage together (Fig. 9E). However, in the case of *baggāra* 2, the builders brought the hood-ends together at a dedicated, though still lightweight, sternpost that is set along the rake of the hood-ends (Fig. 9F): at the time of inspection, there was no surviving stitching holding this joinery together, but holes indicate it had once existed.

The planks of the *fashīn* are aligned using concealed dowels, and the whole held in place by two cheekpieces, the lower one lashed in place, and the upper one nailed.

Planking

The planking of the *baggāras* is *c.* 25 mm—being 1 inch—thick with a surface kerf that is straight and parallel but of variable spacing, consistent with use of a band saw (Williams, 2008: 114). The Imperial dimension and machine-cutting technique are suggestive of a long-distance commercial timber-supply chain. The bituminous coatings on the planking made it difficult to establish how the planking had been cut, although the authors suppose the through-and-through method was used (Kentley, 1985: 307). The species of timber used for the planking is/are unknown.

The fayed edges of the planking are largely obscured by neat seams, wadding, and bitumen, making close inspection of any tooling difficult. However, a gaping scarf joint on *baggāra* 2 revealed a variability on the joint's faying surfaces consistent with use of an adze or chisel—common tools in regional boatbuilding (Agius, 2002: 141; al-Salimi and Staples, 2019: 189). The same joint also revealed the deployment of dowels driven obliquely from one plank-end to the other, from outboard to inboard, securing the scarf. Meanwhile, the necessary tapering of the breadth of the planking along its length to realize the overall hull shape, as well as variation of the angle of the planking edges to achieve watertight seams, would also have required the skilled use of an adze, or perhaps a plane. Because the builder cannot access sewn seams after the stitching is complete, the kind of caulking seen in the region's nailed vessels cannot be applied: instead, luting is necessary (see below).

All three *baggāras* show their builders' preference for diagonal scarf jointing of the planking (Fig. 10), in contrast to the butt joints seen, for example, on the

Belitung (Flecker 2000: 206) and Phanom-Surin wrecks (First Regional Office of Fine Arts, 2016: 45, fig. 45; Guy, 2017: 179, 181: figs 1–2). They also show a broadly similar conception in overall planking arrangement: with three full strakes immediately above the keel, two immediately below the sheer line, and the roundness of the hull amidships achieved via the insertion of one or more drop-strakes between full strakes 3 and 4. Beyond that, however, they differ from each other in significant respects. *Baggāra* 3 shows the most consistent and symmetrical approach to planking. Both sides follow the above concept closely, with a single drop-strake on each side (Fig. 10). The builder's positioning of scarf joints on the upper strakes is also highly systematic, with port and starboard scarf mirroring each other, and a scarf set forward on one strake alternating with those on the strakes above and below set aft, thus distributing the weak points created by the scarfs. The only asymmetry on *baggāra* 3 was a scarf joint close to the forward end of the port garboard strake, and a small stealer in the third starboard strake, perhaps inserted to deal with a plank imperfection. Meanwhile, the through-beams pierce strake 5 centrally on both sides. Neither of the other *baggāras* achieve such symmetry.

Baggāra 1 has some notable divergences from the general planking concept (Fig. 10). There is a tendency below the turn of the bilge to use planks of varying width, necessitating joggle jointing not found in *baggāra* 3, while the drop-strakes and upper strakes tend to comprise numerous short timbers. The implication is that the builder(s), or perhaps repairers, of *baggāra* 1 were more constrained in their timber options than those of *baggāra* 3, while seeking to achieve a similar overall planking concept.

The most irregular planking occurs on *baggāra* 2 (Fig. 10). The same broad zones are apparent, but are much more irregular. Both sides have a single plank comprising the garboard strake. On the starboard side, this is followed by two more single-plank strakes, as in *baggāras* 1 and 3. However, on the port side, the place of strakes 2 and 3 is taken amidships by a single, large, 'double-width' plank. Forward and aft of this wide plank, strakes 2 and 3 'reappear' as separate planks: Kentley (1985: 307) observes a similar combination of two strakes into what he calls a 'broad strake' in some sewn *masulas* in Orissa, India. Meanwhile, around the turn of *baggāra* 2's bilge, there is on both sides of the vessel a highly irregular arrangement of drop-strakes, stealers and graving pieces comprising multiple timbers (Figs 2 and 10). Above, the two upper strakes complete the hull in a regular manner on both sides.

This variation in planking plans between the three *baggāras* is informative. The uniformity and symmetry of *baggāra* 3 suggests an experienced builder with a clear hull concept in mind and planks available of sufficient quality, quantity, and length to execute it. This uniformity perhaps also suggests a vessel near the start of its working life, before the disruption of subsequent repairs. However, the planking plans of *baggāras* 1

and 2 show a variability in execution—if not overall conception—that stands in marked contrast. However, they suggest no less skill or overall conception in the minds of their builders. What they do suggest is an imperative to economize on timber and optimize what was available. This is suggested in the proliferation of shorter timbers and scarf joints, particularly above the waterline. The incorporation of relatively short and/or broad planks in *baggāras* 1 and 2 likewise suggests the opportunist incorporation of available, perhaps reused, timbers.

The incorporation of a single, extra-broad plank amidships on the port side (only) of *baggāra* 2 appears a particularly unexpected choice on the part of the builder. As the construction drawings for this vessel show, this has a particularly deleterious effect on hull symmetry. Inexperience or a lack of skill on the part of the builder is an alluring explanation. However, the multiple small timbers used around it to create the drop-strake and incomplete strake 4 actually imply a certain confidence in the builders' stitching skills, and a creative improvisation in the deployment of limited timber resources. Given the asymmetry, it is possible, perhaps likely, that the incorporation of this timber was part of a later repair.

There is no visible evidence on the *baggāras*—largely due to the bitumen coating—to indicate how the curvature of individual planks was achieved. It may have been through the application of fire, together with twisting force, as observed directly by Cooper and Ghidoni in Zanzibar,⁷ and also Shaikh *et al.* (2011: 152) in Goa, Kentley in Sri Lanka (2003a: 171–173) and Wenban-Smith in Tanzania (1963: 167, 171). Ghidoni (2019: 368) also used this approach in the project to build a replica of the *beden seyad* in Oman. Kentley (1985: 307) reports no use of heat or steam to shape the planking of the sewn Indian *masula*, however.

Planking and framing sequence

The builder(s) would have fixed the two pre-shaped garboard strakes to the keel using the dowels and continuous sewing technique as mentioned. They would probably have used a traditional forked marking gauge (Ar. *qalam*) made from a partly split stick to mark with a coloured pigment the portions of the plank requiring reduction (al-Hijji, 2001: 150). Achieving a close fit against the keel would also require the builder to adze or chisel the lower faying surface of the garboard to an angle that would have to change progressively along its length: acute amidships, and obtuse at the ends. The precise manner of stitching the garboard strakes is set out below.

With the garboard strakes fixed, the second and third strakes could then be added progressively. At this point, the sharp curvatures of the strakes probably still require the planks to be heat-shaped, possibly with weighted levers applied amidships, in order to ensure the required beam of the complete hull.

The framing timbers of the QM *baggāras* were, without exception, grown crooks selected for their natural approximation to the curvature of the hull at the desired point of attachment. While the planks were probably sourced further afield, these timbers might have been sourced locally, with *Ziziphus spina christi*, *Acacia nilotica*, or varieties of mangrove as species candidates, depending on place of construction (Vosmer, 1997: 218–219; 2005: 96–97; Weismann *et al.*, 2014: 427, 429; Agius *et al.*, 2016: 143–146). These would have been shaped by axe and adze, probably using a bendable metal rod (or similar) as a mould to transfer the curvature from the hull and a *qalam* to mark where material needed to be removed; the initial curvature of the hull itself would have been previously established, probably by setting four or so frame stations, the dimensions of which would have been transferred from a pre-existing vessel or moulds. The upper sided face of each floor has recesses to accommodate and prevent abrasion of the lashings.

The floor-timbers of the *baggāras* do not, generally, extend beyond the seam between the third and fourth strakes (or third strake and drop-strake). Hence, they could have been attached at this stage in the process in order to brace the hull in its achieved shape. This is the approach that the builders of the Omani *battīl* took (Vosmer, 1997: 224), as did Severin (1985: 285) in his *Sohar* reconstruction. Prados (1996: 104) says this approach was also feasible on the Yemeni sewn *sanbūq*, and we suggest it might also be the case for the similar Omani *kambārīs* that Weismann *et al.* (2019) describe. The subsequent planking could afterwards be built up as far as the penultimate strake, presumably using the same bendable metal rods as moulds. This interpretation nuances discussion of longitudinally sewn boats generally as being inherently of ‘shell-first’ construction (Pomey and Boetto, 2019: 6–7).

Once the *baggāra* builders reached the penultimate strake, their attention would have turned to fixing the four through-beams that brace the upper portion of the hull. There is some variety between the *baggāras* in how the beams are accommodated into the planking. In *baggāras* 1 and 2, recesses are sometimes cut into both the penultimate and sheer strakes (Fig. 10B), while in others, only the sheer strake is recessed (Fig. 10A), with the beam simply sitting on the top edge of the penultimate strake. In *baggāra* 3, full holes have been cut through the sheer strakes (Fig. 10C). In all cases, we presume the builders notched the beams in order for them to sit on the plank and prevent lateral movement, but could not confirm this because of the extant beam-end stitching.

Two of the beams on *baggāra* 1 are probably reused keels, given the proliferation of obliquely set vestigial dowels found along their length; a similar reused piece formed the outer stem of *baggāra* 2.

Once the builders had fixed the through-beams and sheer strake in place, the natural-crook half frames could be shaped with an axe or adze, again using a

qalam and mould, and lashed into place within the hull in a manner discussed below. Again, the sided face of each timber has recesses cut into it to accommodate the lashings.

With all major structural timbers fixed, the builders could fit the gunwales and deck planks into place—this time with nails. The *fashīm* and prow timber could be added any time after the hull planking was complete and the relevant posts were in place. Both are attached to their counterpart timbers using internal wooden dowels and held in place by cheek pieces. In addition, the prow timber is fixed with light and loosely spaced lashings (Fig. 11). In all three *baggāras*, the lower cheek pieces are lashed into place, while the upper ones are nailed.

Fastenings

Three principal types of fixing occur on the QM *baggāras*: stitched and lashed cordage (Table 2); wooden dowels (Table 3); and ferrous nails. Stitching and dowelling are the main fixing methods on the hull, being used to edge-join planking and attach major timbers such as the keel, posts, and beams. Lashing is used to connect the framing timbers and lower cheek pieces to the hull planking.

The cord used to stitch and lash all three *baggāras* is two-ply and (mostly) S-laid, made from a fine, relatively pale plant fibre of unknown species. It is generally 3 mm in diameter, sometimes 4 mm (Table 2). Ethnographic and experimental-archaeological parallels suggest coconut coir as a likely candidate, but no scientific species identifications have been made.

The function of the wadding is to tension the cordage, not least by swelling when wet, thus improving the water-tightness of the seam beneath; it also cushions the cordage against wear, especially at the edges of the sewing holes, and against the shock of hull impacts (Kentley, 1996; Vosmer, 2005: 175). For the most part, the inboard wadding of the *baggāras* comprises long strands of an unidentified grassy plant material laid loose along the seams before being over-sewn (Fig. 12A, B). Where wadding occurs outboard, it comprises a coarse-fibred cordage (Fig. 12C).

Stitching of the keel and posts

The intact nature of the QM vessels again made understanding of the stitching process around the keel and garboard strakes challenging. Outboard, the cross-stitched cordage, running in a |X|X|X|X| pattern along the seam between keel and garboard strakes, is a familiar feature of the western Indian Ocean sewn-boat tradition. The wadding beneath comprises a continuous run of a similar cordage looped back and forth along the length of the seam (Fig. 12C). What is striking, however, is the presence of the same cross-stitch configuration—this time with grassy wadding beneath—overlying the upper face of the keel inboard, crossing between the port and starboard strakes (Figs 12A and 13). This strongly suggests that both

Table 2. Indicative characterisations of the cordage of the Qatar Museums sewn boats

	Baggāra 1		Baggāra 2		Baggāra 3	
	Diameter (mm)	Description	Diameter (mm)	Description	Diameter (mm)	Description
Keel stitching	3	2-strand, S-laid cord; fine, buff-coloured fibres	3.5	2-strand, Z-laid cord; fine, buff-coloured fibres	2.9	2-strand, Z-laid cord; fine, buff-coloured fibres
Outboard keel wadding	6.5	2-strand, Z-laid cord; fine, reddish-coloured fibres (coir?)	5–6	2-strand, S-laid cord; coarse, buff-coloured fibres	10	2-strand, Z-laid cord; coarse, reddish-coloured fibres (coir?)
Inboard keel wadding	n/a	Grassy leaves	n/a	Grassy leaves	n/a	Grassy leaves
Stempost stitching	3	2-strand, S-laid cord; fine, buff-coloured fibres	3	2-strand, Z-laid cord; fine, buff-coloured fibres	3	2-strand, Z-laid cord; fine, buff-coloured fibres
Outboard stem wadding	8–9	2-strand, Z-laid cord; fine, reddish-coloured fibres (coir?)	5–6	2-strand, S-laid cord; coarse, buff-coloured fibres	10	2-strand, Z-laid cord; coarse, reddish-coloured fibres (coir?)
Inboard stem wadding	n/a	Grassy leaves	n/a	Grassy leaves	n/a	Grassy leaves
Frame lashing	4	2-strand, S-laid cord; fine, bitumen-stained fibres	3.3	2-strand, S-laid cord; fine, bitumen-stained fibres	3.2	2-strand, S-laid cord; coarse, bitumen-stained fibres
Planking stitching	4	2-strand, S-laid cord; fine, bitumen-stained fibres	3	2-strand, S-laid cord; fine, bitumen-stained fibres	3	2-strand, S-laid cord; coarse, bitumen-stained fibres
Planking wadding	n/a	Grassy leaves	n/a	Grassy leaves	n/a	Grassy leaves

*Spot sampled, where it was possible to access

Table 3. Indicative dimensions of the dowels of the Qatar Museums *baggāras*

Dowel diameters (mm)*	Baggāra 1	Baggāra 2	Baggāra 3
Keel	12	10	7.5
Planking edges	6	7	n/a
Outer stempost	12	8	7

*Sampled where possible to access

garboards were stitched into place at the same time, as part of a unified stitching sequence. We know of no parallel to this among other regional sewn boats, where normally each garboard is attached independently (cf Vosmer, 1997: 234, fig. 25). A hypothetical reconstruction of the sequence is shown in Figure 14. The process starts with a cord passed through one of the holes drilled horizontally through the keel such that the midpoint of the cord's length sits at the midpoint of the hole. The rope is then locked into place using a temporary peg, and the stitching proceeds with *both*

ends of the rope active at the same time, the trajectory of each mirroring that of the other as they cross from port to starboard, and from garboard to keel.

The stitching is run through holes of 10–14 mm diameter drilled horizontally through the keel between port and starboard, and through others drilled through the garboard strakes directly above the keel holes. The authors' opportunistic sampling indicated that the keel holes—and hence the garboard stitching holes corresponding to them—are typically spaced 100–120 mm apart on *baggāras* 1 and 3, and 85–95 mm apart on *baggāra* 2. The distance of the holes in the keel and garboard strakes from the seam between these timbers can be inferred as approximately 25 mm on *baggāras* 1 and 2, and 35 mm on *baggāra* 3, based on measurement of intact stitches amidships. The holes in the strakes are plugged with wooden pegs following stitching to maintain the water-tightness of the hull. Those drilled through the keel are not, since they do not impact water-tightness.

The cordage comprising the outboard wadding of both *baggāras* 1 and 3 is two-ply, Z-laid, and with a

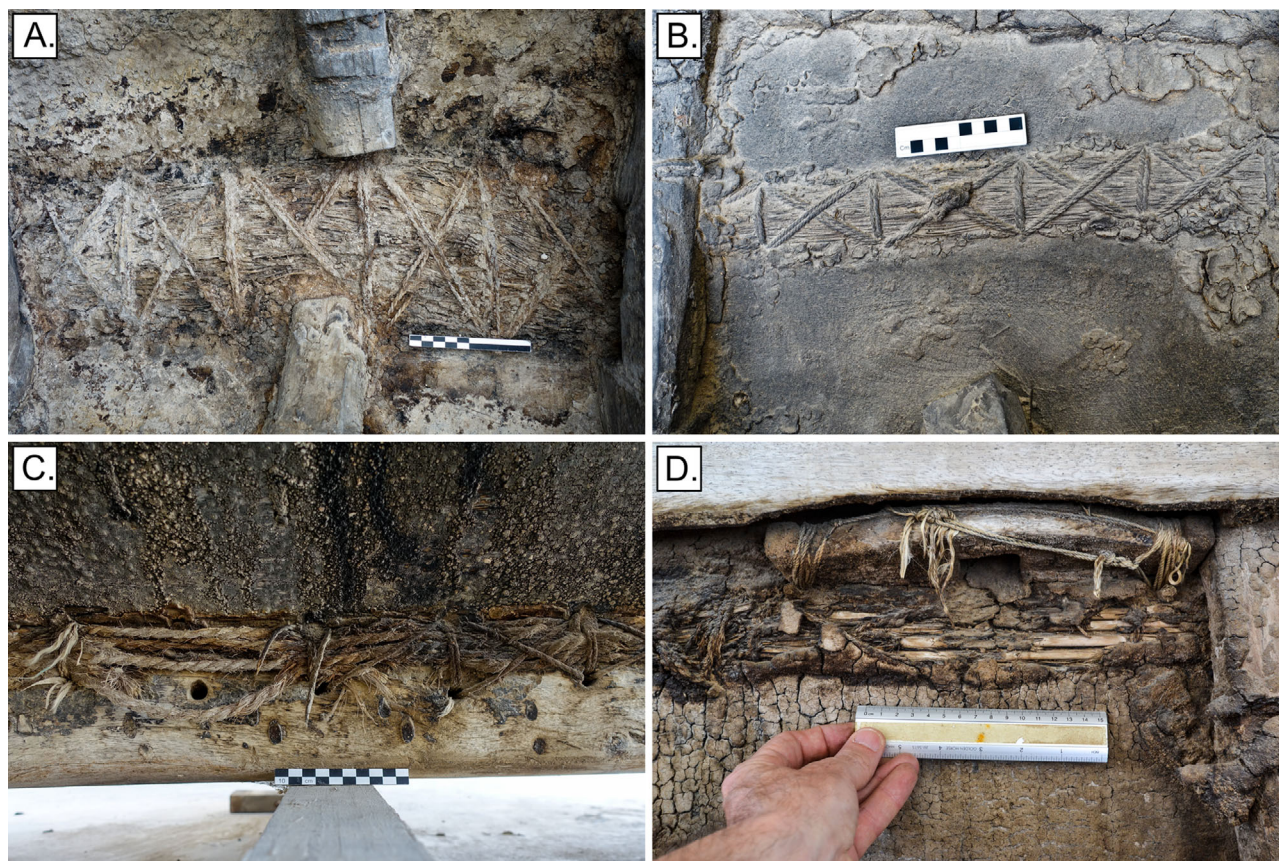


Figure 12. Wadding materials on the QM *baggāras*: A) grassy wadding over the inboard seams between the garboards and the keel on *baggāra* 1; and B) on the planking seams of *baggāra* 3; C) fibre ropes stretched along the outboard seam of the keel and garboards on *baggāra* 2; D) a small section of possible repair wadding made of a reed-like plant inboard on *baggāra* 1. (Images: John P. Cooper, Alessandro Ghidoni, Chiara Zazzaro).

coarse and reddish fibre suggestive of coir or date-palm (Table 2). The *baggāra* 1 cordage was narrower, however, at 6.5 mm diameter, compared to 10 mm on *baggāra* 3. On *baggāra* 2, in contrast, the two plies of the cord were S-laid and comprised a coarse buff-coloured fibre.⁸ This use of cordage alone as a wadding material is not reported in other regional ethnographic studies, although a number of authors report its use over a core of coir fibres (Varadarajan, 1998: 68; Kentley, 2003a: 150; Shaikh *et al.*, 2011: 152–153; Shaikh, 2019: 382–383) and in several experimental reconstructions (Vosmer *et al.*, 2011: 417; Ghidoni, 2019: 367, 369, 375; Staples and Blue, 2019: 319–322, 329).

The builders of the QM *baggāras* fastened the ‘false’ outer stem and stern posts—whether the latter was a dedicated post, or the first plank of the *fashīn*—using the same sewing technique as the keel-garboard assemblage: a double-strand cordage arranged in a IXIXIXI pattern over wadding made of ropes outboard, with the same IXIXIXI pattern over grass wadding inboard. The stem sewing is actually a continuation of that of the keel and garboards. At the stern, the post stitching is separate, since the keel-

garboard stitching continues aft to fasten the lower edge of the *fashīn*.

Stitching of the hull planking

The stitching system used to edge-join the planking of the *baggāras*—and indeed the *kettuvallams* discussed below—is reflective of the wider ‘single-wadding’ tradition of the western Indian Ocean, its chief characteristic being the cross-stitching over wadding inboard and vertical recesses for the stitching outboard (Fig. 15) (Yajima, 1976: 25–27; Prados, 1996: 101–103; Vosmer, 1997: 232; Chittick, 1980: 301–303). Similar approaches are taken in the Omani/Yemeni *kambārīlsanbūq* (Bowen, 1952: 209–212; Prados, 1996: 101–103; Vosmer, 1997: 231–234; Camelin, 2006: 105; Weismann *et al.*, 2019) and Somali *beden* (Chittick, 1980: 301–303). This technique occurs on some of the 11th–15th century timbers found in al-Balid in Oman (Belfioretti and Vosmer, 2010: 113; Pavan *et al.*, 2018: 228; Vosmer, 2019: 308) as well as the 12th–15th century sewn timbers from Quseir al-Qadim in Egypt (Blue, 2006: 280–282). It stands in contrast to the ‘double-wadding’

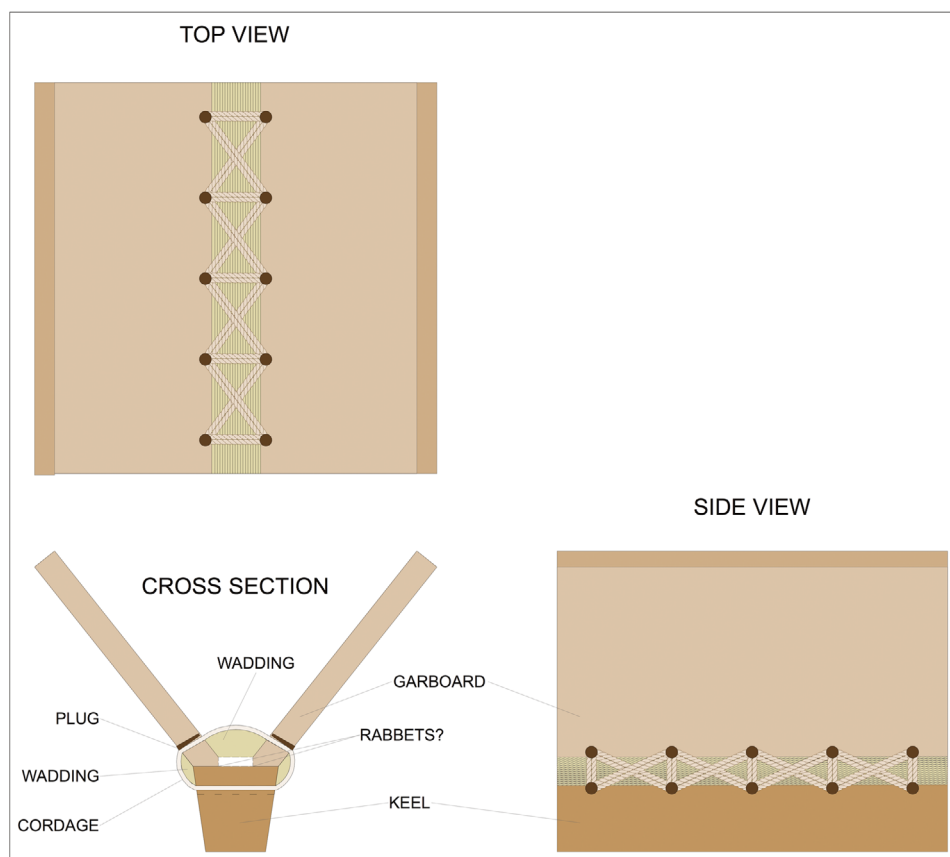


Figure 13. Diagram representing the sewing pattern of the keel-garboard assembly of the QM *baggāras*. (Image: Alessandro Ghidoni).

approach adopted in earlier periods, whereby wadding is laid along both the inboard and outboard seams, and overstitched on both sides—for example on the Belitung and Phanom-Surin ships (Flecker, 2000: 206; 2001: 339; Vosmer, 2019: 307) and at least some of the 11th and 12th century timbers from al-Balid (Vosmer, 2017: 198–200; 2019: 308; Pavan *et al.*, 2018: 228).

Grassy material is rarely noted as wadding in other works on regional sewn boats: Kentley (1985: 307; 2003a: 140) does report the use of types of ‘marsh grass’ in *masulas* in India, and notes its propensity to rot more rapidly than coir, requiring the vessel to be re-sewn every season. Other authors more commonly cite the use of loose coir fibres (Vosmer, 1997: 232; Fenwick, 2019: 387–388), as well as palm leaves (Bowen, 1952: 205; Prados, 1996: 102; Weismann *et al.*, 2019: 355), unspecified local ‘plants’ (Chittick, 1980: 301, 303), a compound of pounded mangrove bark, coir, and strips of dried leaves of doum palm (*Hyphaene thebaica*) (Hornell, 1941: 61), and even ‘synthetic’ materials (Prados, 1996: 102). The *kambārī* in the OAM collection has strips of an unidentified leaf as wadding on its keel-garboard joint.⁹

For the most part, the inboard wadding on the hull seams of the QM *baggāras* comprises the same

grassy material used in the inboard keel wadding. The only variation is in areas of repair, for example on *baggāra* 1, where a stiff, pale yellow, round-stemmed reed-like plant had been used, probably in a repair (Fig. 12D).

For the most part, the same cordage appeared in the stitching of the hull planking as on the keels, stems, and sternposts.

Lashings of frames and cheek pieces

The framing system of the *baggāras* consists of half-frame pairs alternating with timber sets comprising a floor and two futtocks. All of these timbers are lashed into place using the same cordage as was used in sewing the planking. The timber in question is shaped by adze and set in place over the already sewn planking. The lashing positions are identified, and pairs of holes drilled through the hull planking on either side of the intended timber position. The lashing is passed through these holes and around the timber, and secured inboard with a knot on each moulded side (Fig. 16). Rebates are again cut into the outboard face of the planking in order to recess the cordage. The lower cheek pieces aft are also lashed. Each is fixed at four points: two connecting it to the *flashīn* and two to the hull planking (Fig. 17). Unlike on the framing timbers, the lashings

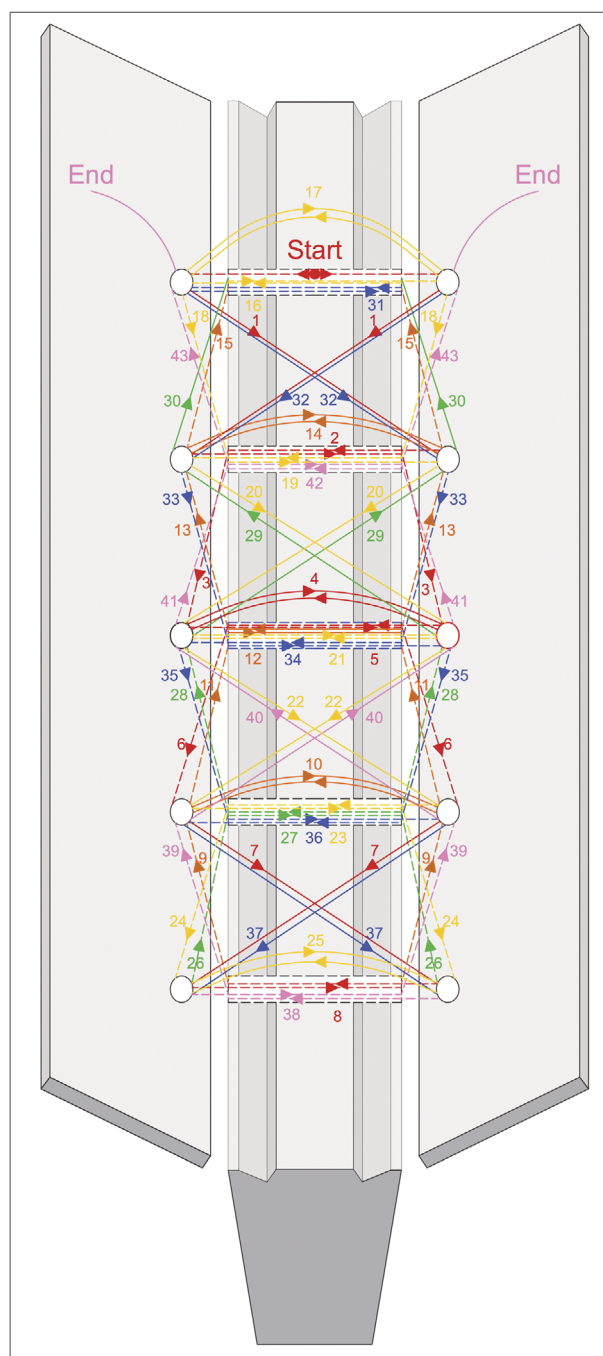


Figure 14. Hypothetical reconstruction of the sewing sequence of the keel-garboard assembly of the QM *baggāras*. (Image: John P. Cooper).

pass through two holes in the planking/*flashīn* instead of four.

Stitching of through-beams

Each *baggāra* has four through-beams projecting through each side of hull. The two amidships are connected to each other by nailed carlings; the two others support the decks. All are sewn to the hull in

an elaborate ‘six-pointed’ sewing pattern that passes through six holes drilled in the planking and a 10–12 mm hole drilled vertically through the outboard section of the beam (Fig. 18A). Two of the planking holes are set directly above and below the beam hole, with the other four are in pairs aligned vertically on either side.

The beams are sewn with cordage that is similar—but thicker—to that used in the plank-to-plank stitching. Outboard, the stitching is mostly over wadding; inboard, the joint is partially covered by a clamp coated with a thick layer of bitumen and fish oil, making it difficult to determine whether there is also wadding inside—there is none on the similar Omani *battīls*, and was none on the Belitung wreck.¹⁰ The outboard wadding comprises various materials: mostly thick cordage, but also loose fibres (perhaps coir or date-palm), grass, and cotton rags—the latter perhaps as a repair (Fig. 19). The thicker, more open, cordage points to an inferior quality. The wadding cordage is typically arranged in two looped bundles of approximately 10–15 ropes each, placed above and below the beam end. This can best be seen on the two midships beams on the port side of *baggāra* 1, where the returns of the ropes are visible (Fig. 18A).

The beam stitching of the QM *baggāras* is almost identical to that of the *battīls* of the Musandam peninsula, Oman (Vosmer, 1997: 224, 227, fig. 13) (Fig. 18C). The only difference is that the six holes on the *battīl* are arranged in two horizontal rows of three above and below the beam because the beams are set too close together to place holes to the sides. The beam fastenings also resemble those of the Belitung shipwreck (Flecker, 2000: 207), albeit less elaborate and on a smaller scale (Fig. 18D).

Dowels

The use of wooden dowels (Table 3) is, as already indicated, closely connected to the process of continuous stitching. They are used to align and fix the garboard strakes to the keel (Fig. 9A), hull planks to hull planks along both edge and scarf joints (Fig. 20A), to edge-join the *flashīn* planking (Fig. 20B) and fix the ‘false’ stem and prow timbers (Fig. 20C). They are also used in the scarf joints of the gunwale timbers, even though these are otherwise nailed in place.

Iron fixings

There is a clear correlation on all three *baggāras* between the use of iron nails and their location with reference to the waterline. Their deployment only where contact with water is minimal implies something about the builders’ attitude towards the suitability of nails for joints that are extensively immersed. This is best seen in the cheekpieces. In all vessels, the lower aft cheekpieces are lashed to the hull, while the upper cheekpieces—forward and aft—are nailed. Likewise, the gunwales, the inwales set above the fore and quarter decks, as well

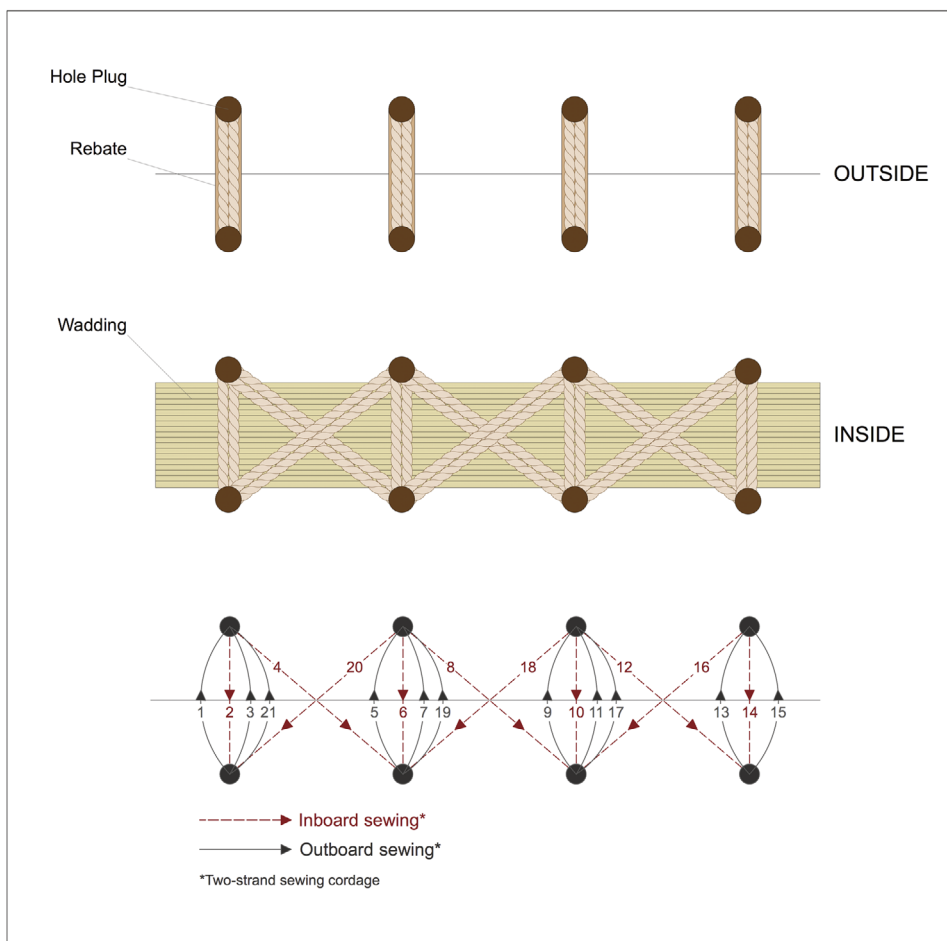


Figure 15. Diagram representing the pattern and sequence of the plank-to-plank sewing of the QM *baggaras*. (Image: Alessandro Ghidoni).

as the deck planking itself, are nailed in place: again, all of these are far above the waterline.

Bitumen-based coatings

The *baggaras* are covered extensively, both inboard and out, with a thick, black coating of varying consistency that the authors interpret as compounds of bitumen, a naturally occurring, highly viscous hydrocarbon (Fig. 21). It coats most of the planking, stitching, and wadding, waterproofing and protecting them from biological attack and physical damage. It is entirely absent from the through-beams, gunwales, deck planks, and (on *baggaras* 1 and 3) the upper cheek pieces, and it is less apparent in the bilges, either because it was never put there or because it has rubbed away. More recently, the hulls have been treated with fish oil.

Although no chemical analysis has been done, the bitumen coating appears more adulterated inboard than outboard. Inboard, it is generally thicker, particularly on the sides, where it is prone to desiccation cracks around tessellations that crumble easily (Fig. 21A). Outboard, the coating appears generally less adulterated—to the extent, sometimes, of

appearing shiny (Fig. 21B). Where it has been applied more thickly, it has a tendency to show signs of running due to heat, particularly on the sides of the hull; where desiccation cracks form, the resultant tessellations tend to remain strongly adhered.

This difference in the bitumen appearance inboard and outboard might be explained by deliberate choices in the mixing of the bitumen for each area. It might be the case that more adulterated mixes of bitumen were applied inboard to reduce melt and stickiness, while less adulterated bitumen was applied outboard to enhance its waterproofing qualities. However, it might equally be incidental: the smooth outboard surfaces of the hull make it easier to apply the bitumen and obtain an even coating, whereas the presence of frames, cordage, wadding, and other elements make this more difficult inboard, perhaps resulting in a less-polished layer. Moreover, the outboard bitumen is continuously washed by seawater, while on the inside it is regularly covered by fish, matting, nets, fish oil, and other substances, making it progressively more adulterated over time. The interior of the hull is also the most exposed to the sun, which can cause the bitumen to

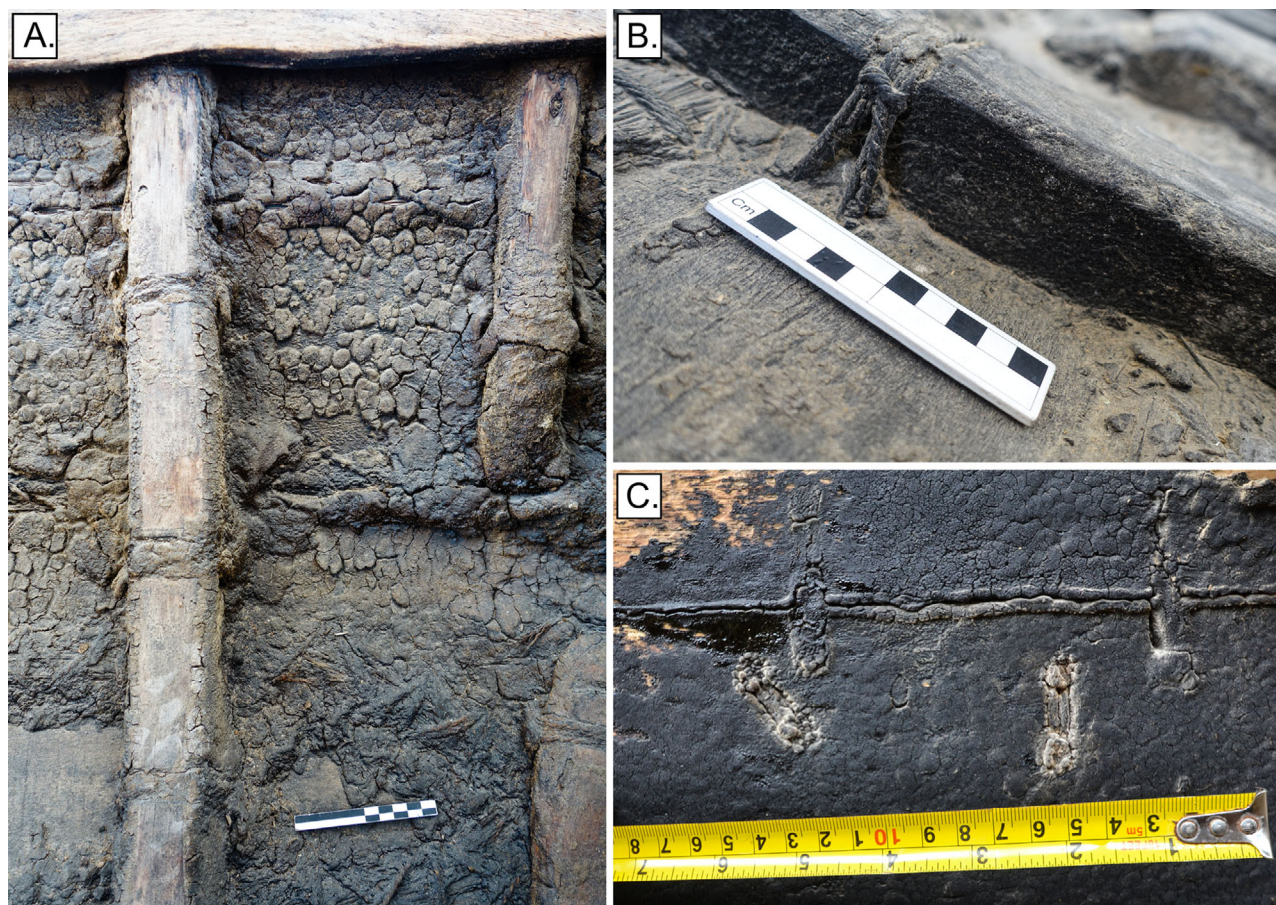


Figure 16. The frame lashing of the QM *baggāras*: A) view of a half-frame inside the hull of *baggāra* 1; B) close-up of a frame fastened by cordage threaded through holes in the planking of *baggāra* 3 and recessed in a rebate carved on the top side; C) the frame lashing pattern visible on the outside of the hull of *baggāra* 3, below the planking seam. (Images: John P. Cooper, Alessandro Ghidoni, Chiara Zazzaro).

become warm, plastic, and more likely to mix with other substances than on the outside, where the water cools it.

Archaeological bitumen fragments interpreted as coming from boats at the late-6th-millennium BCE site of As-Sabiyah (الصبيية) and mid-3rd-millennium Ra's al-Jinz (رأس الجنز) sites suggest that boatbuilders in the distant past actively created bitumen compounds (Connan *et al.*, 2005: 55). Materials such as sand, dust, or crushed vegetal matter might have been added to the heated bitumen before application in order to make it easier to handle or go further, as well as being more resistant to melting, running, and abrasion following application.

Investigation into, indeed awareness of, the use of bitumen as a protective coating among plank-built vessels of the western Indian Ocean has generally been limited (*contra* Burger *et al.*, 2010: 384); more familiar is the white compound of lime and tallow—known in eastern Arabian Arabic as *chunam* (al-Salimi and Staples, 2019: 223), and in western Arabian Arabic as *shaham* (Agius *et al.*, 2014: 155–156)—used for anti-fouling the exterior of the hull below the

waterline, and a compound of shark-liver oil and resin for the upper parts (Hawkins, 1977: 38, 73; Hornell, 1942: 12; Vosmer, 1997: 203–204; Agius, 2002: 153; Agius *et al.*, 2014: 155–156). This is not to say that bitumen coatings are unknown in the wider region and broader chronology. Until recently, boatbuilders on the rivers and marshes of Iraq used it extensively on both reed-bundle and plank-built craft (Thesiger, 1954: 277; Ochsenschlager, 1992: 49–53, 62; 2004; McGrail, 2001: 64–67). Moreover, archaeological and textual evidence show its use in waterproofing reed-bundle and (to a lesser extent) plank-built boats in ancient Mesopotamia, the Gulf, and Oman (Cleuziou and Tosi, 1994; 2000; Connan *et al.*, 2005; Carter, 2006; 2008: 97–101; 2012: *passim*; Agius, 2008: 113; Badel and Kramm, 2014).¹¹ Blue (2006: 281) also found a material on both sides of the Quseir sewn planks that she interpreted as bitumen or pitch. Meanwhile iconographic representations of black hulls in the *Maqāmat* of al-Hariri (Bibliothèque Nationale, Ms Arabe 6094, fol. 68, in Agius, 2008: 152) and a number of Persian miniatures (Eastman, 1950: 156, plate XII) may reflect—though certainly do not prove—the past



Figure 17. The lower starboard cheek piece of *baggāra* 3. (Image: Chiara Zazzaro).

use of bitumen as a hull coating. Despite this breadth of evidence, the QM *baggāras* are the only surviving seagoing vessels with bitumen coating in the western Indian Ocean known to the authors.

The use of bitumen is not inevitably associated with sewn construction. Bowen (1952: 212), Prados (1996: 105) and Weismann (2019: 348) all note fish oil on the MFL *kambārī*, while two of the present authors (Cooper and Zazzaro) observed lime mix on the remnants of a sewn *sanbūq/kambārī* encountered in Aden in 2008.¹² Indeed, the use of lime-tallow mix is a practice of long standing on sewn vessels, with traces of lime compound found as luting on the 8th-century-CE Phanom-Surin and 9th-century-CE Belitung wrecks in Thailand and Indonesia, respectively (Flecker, 2000: 203, 204; Guy, 2017: 192; Vosmer, 2019: 310). Experimental sewn-boat projects such as the *Sohar* and *Jewel of Muscat* have also deployed these coatings rather than bitumen (Severin, 1982: 68; 1985: 283; Vosmer *et al.*, 2011: 216; Vosmer, 2019: 309, 422)—although Severin (1985: 281) opted for coconut oil rather than shark-liver oil.

Luting

The intact state of the QM *baggāras* means that the presence and nature of any luting applied to the faying surfaces of the hull planking cannot easily be established. It certainly would be expected: the seams of sewn hulls must be made watertight before they are covered over by wadding and stitching (Vosmer *et al.*, 2011: 6; Ghidoni, 2019: 369; Shaikh, 2019: 380–84; Vosmer, 2019: 310; Weismann *et al.*, 2019: 351). Vosmer (2019: 310) reports that the process often involves ‘coating each faying surface of the planks to be joined with a luting substance, and sandwiching

a piece of cloth [...] between the planks’. He adds that this ‘luting substance’ is usually resin or bitumen, perhaps mixed with fish or coconut oil, although on the Belitung and Phanom-Surin ships it seems to have been lime putty (Vosmer *et al.*, 2011: 6). Belfioretti and Vosmer (2010: 113) also noted traces of luting on some of the sewn ship-timbers found at al-Balīd in Oman (Pavan *et al.*, 2018: 228). Meanwhile, Chittick (1980: 301) refers to the Somali builders of sewn *beden* using ‘pitch (obtained commercially)’ as luting. Given the abundance of bitumen found on the QM *baggāras*, it might be surprising if this was not also the substance used for the luting.

Propulsion and steering

The presence of large square holes set along the gunwales of the QM *baggāras*, with brackets sewn into the planking directly below them, indicate housings for thole pins, and hence that the *baggāras* were rowed. *Baggāras* 1 and 3 have two such holes per side, indicating two rowing positions. In contrast, *baggāra* 2 has four holes per side, although two are too close together for them to be two simultaneous rowing positions: hence there are probably three at any one time (Figs 1–3). The vessels were acquired without oars.

Two obliquely set carlings connecting the two main through-beams on each of the *baggāras* (Figs 1–3) suggest supports for a mast, even though there is no evidence of a mast step, which would have been essential on a vessel with delicate stitching and grassy wadding on the upper face of its keel. The same configuration of carlings also occurs on the nailed Emirati *baggāra* (*‘baqqārah’*; Weismann *et al.*, 2014: 421), as well as on the nailed Dubai *shāhūf* in the Deutsches Museum, Munich, and the nailed Omani

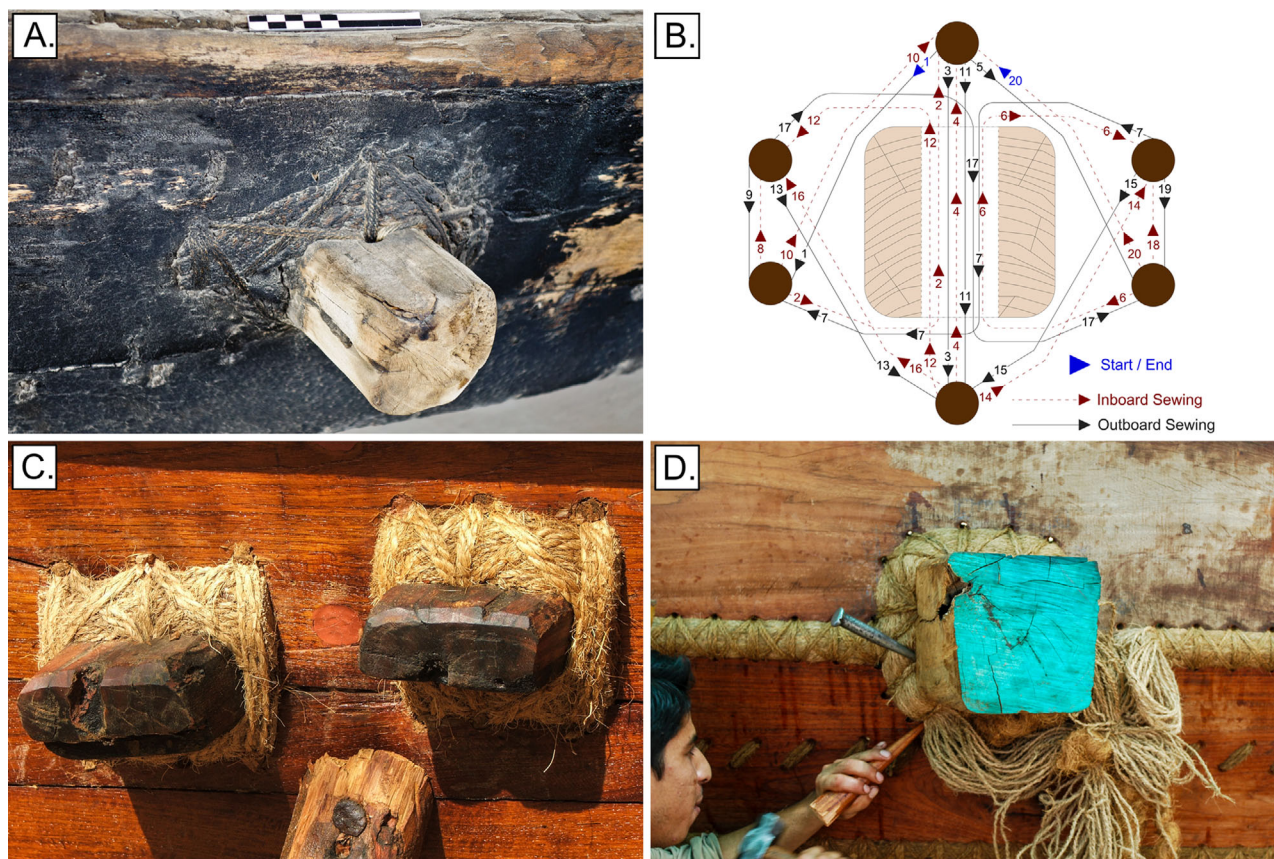


Figure 18. A) Outboard lashing of a through-beam on *baggāra* 3; B) hypothetical reconstruction of the sewing sequence of the QM *baggāra* through-beams based on Vosmer's reconstruction of the sewing of a beam on a *battil* (2005: 179, fig. 4.2.5); C) the through-beams at midships on a *battil*, Muscat, Oman. Note the similarities with the *baggāra* through-beams; D) through-beam of the *Jewel of Muscat* reconstruction, based on the 9th-century Belitung wreck. (Images: Chiara Zazzaro, Alessandro Ghidoni).

'*zarooqa*' (Weismann *et al.*, 2014: 422; Vosmer, 1997: 227): the last two of these have a mast step set below the carlings. Vosmer interprets the *zarooqa* configuration as vestigial of a time when that vessel, now exclusively rowed, was sailed. The same might be true of the QM *baggāras*.¹³

The QM *baggāras* had no rudder, nor indeed any apparent fittings for one. The construction drawings of the very similar (but nailed) Emirati *baggāra* in Weismann *et al.* (2014: 421) depicts a medial rudder secured onto the *fashīn* by ropes passed through holes in the rear plank of the *fashīn*, and guided into place by aft extensions to the two *fashīn* cheekpieces. However, the requisite holes are absent on the *fashīns* of the QM *baggāras*, and the cheekpiece extensions appear too close together to have accommodated a rudder: this suggests that the *baggāras* were steered with their sweeps alone.

The kettuvallams

We now turn our attention to the construction sequence and features of the other sewn-boat type in the

QM collection—the *kettuvallams*. Unlike the defunct *baggāra*, construction of the *kettuvallam* can still be observed in Kerala today: the following observations, made out of context in the QM boatyard, would certainly be enriched by direct observation at their place of making. For now, they must suffice.

Keralite kettuvallam construction

Owing to time limitations, the authors surveyed only one of QM's two *kettuvallams*; both are similar to each other in form, construction, and state of preservation (Figs 4 and 6B). Each is double-ended, relatively flat-bottomed, and of a much slenderer length-to-beam ratio than the *baggāras*. Both bow and stern curve sharply upwards. The vessels have no keel or deck, and are predominantly fastened with cordage using the single-wadding method on the planking, with some use of nails; no dowels are apparent. The only direct evidence of means of propulsion are oar rests and rope rowlocks. An internet search of images of the same type of vessel suggests it is propelled exclusively by oars, and steered using a dedicated steering oar. This is

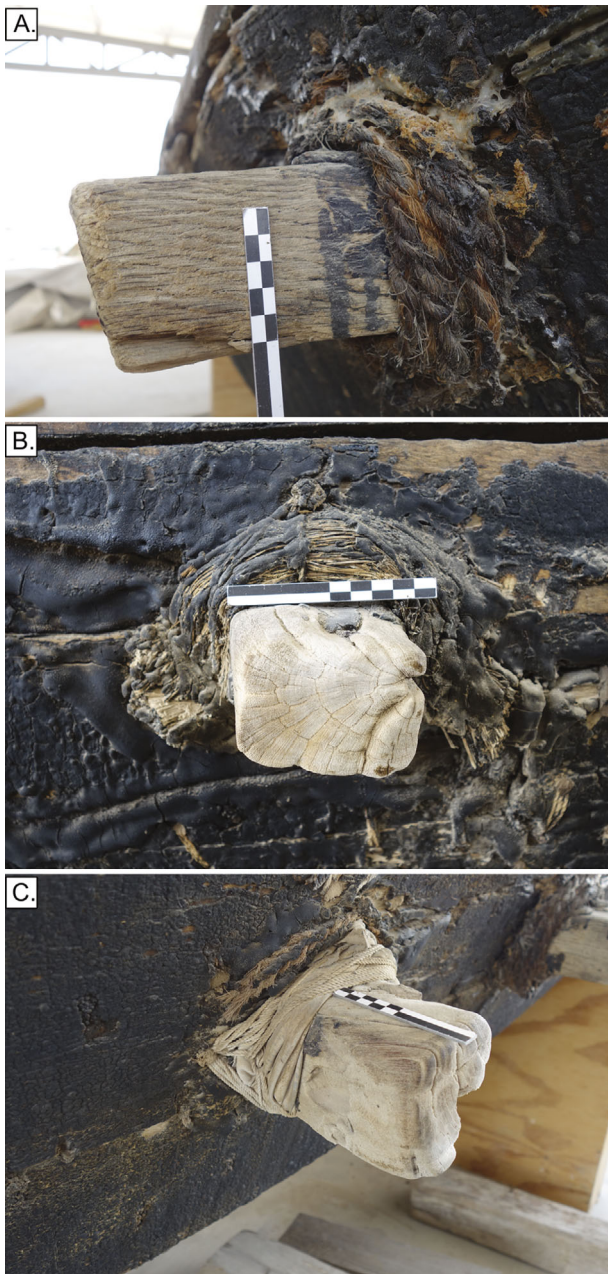


Figure 19. Wadding materials in the through-beam lashings of the QM *baggāras*: A) thick fibre ropes; B) grass wadding on *baggāra* 2; C) cotton rag around two of the through-beams of *baggāra* 1 (Images: Chiara Zazzaro).

also suggested by the positioning of the thwarts, which indicate rowing positions.

The inferred construction sequence of the *kettuvallam* is as follows:

Central strake and posts

Construction begins around a central strake comprising a single plank of the same thickness and width as the other full-length planking. This is edge-joined to the adjacent planks by means of the same continuous



Figure 20. Oblique dowels used on the QM *baggāras*: A) securing a planking scarf joint on *baggāra* 1; B) fixing the *fashīn* to the keel, also on *baggāra* 1; C) fixing the ‘false’ stem and prow timber on *baggāra* 2. (Images: John P. Cooper, Alessandro Ghidoni).

stitching method used for subsequent planks (see below). The ends of the central strake are butted and sewn to the posts, which curve upwards before straightening to an angle of around 42°. The planks are sewn with wadding inboard only, with occasional use of guide nails (see below). There is no visible evidence of the rabbeting of the hood-ends into the posts; a white putty-like substance is noticeable in some small areas in the sewing of the outer post to the planks (Fig. 22).

The posts are capped with decoratively carved finials that are sewn and nailed to the posts. At the bow, this

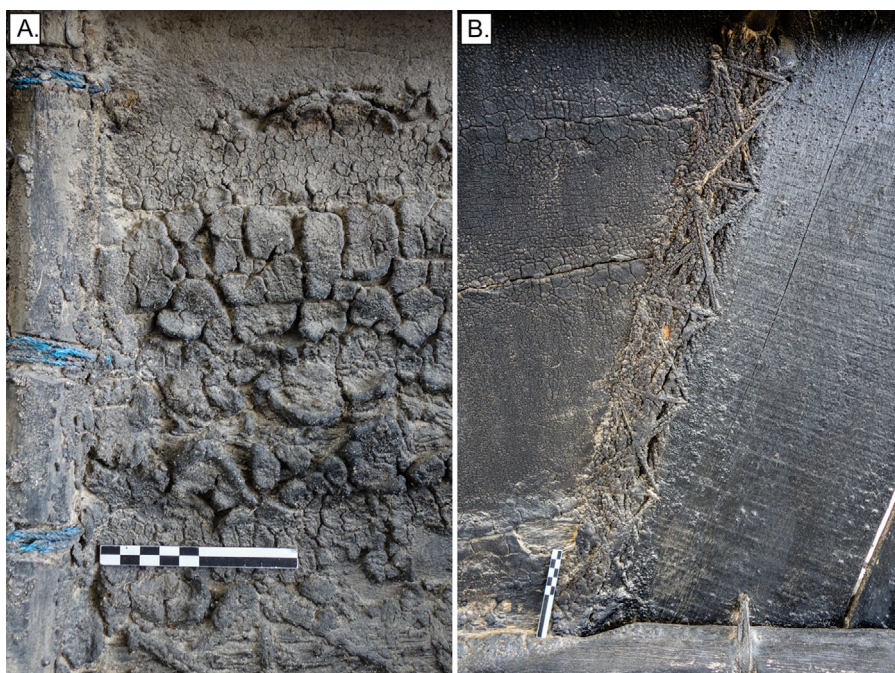


Figure 21. Bituminous coatings on QM *baggāra* 1: A) highly adulterated and friable bituminous coating on the inboard planking and stitching; B) purer and strongly adhered bitumen on the outboard planking (L) and *fashīn* (R). (Images: Chiara Zazzaro).



Figure 22. A white putty-like substance within the stitching fastening the outer post to the planking of *kettuvallam* B. (Image: Chiara Zazzaro).

consists of a single large scroll enfolding a carved fish figure, while at the stern it comprises a more abstract form (Fig. 23A, B).

Outboard, the stem and stern posts each have a painter hole; that of the stern was also used to secure the steering oar (Fig. 24). Two short timbers nailed to either side probably aimed at reinforcing the posts around these holes.

Planking

The hull planking proceeds upwards from the central 'keel' plank. On both sides, the hull has five full-length strakes running from stem to stern, the planks of all being butted and sewn together with internal wadding, with some nails (see below). After the third plank, there is a noticeable chine, after which the hull sides rise almost vertically; there are two drop-strakes at the turn,



Figure 23. Decorative carved finials sewn to the posts of *kettuvallam* B. (Images: Alessandro Ghidoni, Chiara Zazzaro).



Figure 24. Painter holes occur in the stem and stern posts of *kettuvallam* B; the stern hole is also used to secure the steering oar. The two short timbers nailed on either side of the post are probably intended to reinforce the posts. (Image: Alessandro Ghidoni).

which taper forward and aft. Since the sheer line rises sharply at both ends, two or more addition planks are introduced and fastened by nails and screws (Fig. 4), the lowest of these extension planks is also sewn to the sheer plank. The hood-ends of all strakes that run the length of the hull—that is up to the fourth strake—are both stitched and nailed; higher up, they are nailed only (Fig. 25).

The planking is 40–45 mm thick and of unknown species; a straight and parallel kerf of variable spacing again suggests the use of a band saw, as with the *baggāras*. Tool marks on the visible edges of the planking suggest the use of an adze or chisel.

The overall uniformity and symmetry of the planking again suggests a well-established system of construction, as well as readily availability materials. It perhaps also suggests a vessel that is not too old, since

instances of repair seem limited to cracks forming in individual timbers (Fig. 26). There is no visible evidence to indicate how the curvature of the planks was achieved.

A rubbing strake is nailed and lashed to the outer face of the sheer strake (Fig. 27). On the forward half of the hull, a washstrake is loosely lashed to the sheer strake; aft of it a gunwale is attached.

Framing sequence

The *kettuvallam* has 11 sets of frames, each comprising a floor and two futtocks made of naturally curved timbers of unknown species, probably sourced locally (that is, in Kerala). Parallel saw marks are apparent on their moulded faces; these would have been shaped by bandsaw. Each futtock is obliquely butt-jointed to its floor-timber. The framing timbers are



Figure 25. The nailed and screwed hood-ends above the fourth strake of *kettuvallam* B. (Image: Chiara Zazzaro).

joined to the planking by means of widely spaced lashings (see below). Each floor has linear recesses of triangular cross-section on its lower sided face to accommodate the planking stitching and wadding, with one functioning as a limber hole. The floor-timbers do not, generally, extend beyond the seam of the third strake. Hence, as with the *baggāras*, they might have been attached at this stage in order to brace the hull in its achieved shape, before the side planking was added. However, Ransley's observations (2009: 2.106) of the construction of a somewhat different *kettuvallam* in Munruthuruthu, Kerala, suggest that these are added after all the strakes have been built up, along with the other frames.

*Beams and thwart*s

The *kettuvallam* has seven cross-timbers: five forward and two aft. Those furthest forward and furthest aft are essentially thwarts that are fitted directly to the hull's (nailed) upper strakes, one is recessed above to leave space for the rivet. The other five, although also acting as rowing positions, function structurally

as beams. They are accommodated into recesses cut into the penultimate planks and rivetted into it at each end. These beams are recessed below to leave space for the rivet. The rust of the latter suggests it is ferrous: the outboard rubbing strake concealed any evidence of roves. The extension strakes are also recessed to take these timbers. The four beams forward all have rowing positions associated with them, with the forward two of these having only one rowing position each, due to the narrowing of the hull—although one has two thole-pin holes on the same (port) side.

Coating and luting

Throughout the vessel, a dark, oily substance is found inboard and outboard along the seams, although it was worn away to bare wood in many places. Interpreted as a preservative coating, this might be cashew or *kadu* (pumpkin seed) oil (Shaikh, 2019: 380, 382), or otherwise resin (*chundruz*, *khundrus*; Severin, 1985: 285; Shaikh, 2019: 380).

The putty-like substance found occasionally in the seams, resembling *chunam*, could be luting.

Fastenings

As with the *baggāras*, the fastenings of the *kettuvallam* are particularly interesting because they combine a variety of techniques, such as sewing, lashing, nailing, screwing, and riveting.

Plank sewing

The hull planks are edge-joined using continuous stitching over inboard wadding, in a way identical to that used for the *baggāras* (Fig. 28). Small sections of sewing also fix the top edge of the sheer strake to the lower edge of the extension planks at bow and stern. The sewing cordage comprises a single, thin, three-yarn, S-twisted rope, threaded through holes spaced around 60–70 mm apart and set 20 mm from the seam. The cordage appears to be cotton. The wadding is made from a fine fishing net of about 5 mm gauge (Fig. 28A): unlike on the *baggāras*, it is never found outboard. The cordage and wadding materials suggest that the boat was re-sewn relatively recently, using readily available and cheaper materials than the traditional coir.

Plank nailing

The *kettuvallam*'s builders used nails to edge-fasten the planks to facilitate sewing, in a manner analogous to the dowels of the *baggāras*. These are driven obliquely from outboard near the edge, passing through the butted faces of the adjacent planks, at intervals of around 1 m—much further apart than the *baggāra* dowels (Fig. 29A–B). Their heads are recessed into triangular notches.

Hybrid fastening: nailing and sewing

The *kettuvallam* builders used a combination of sewing and nails to join the hood-ends of planks to the posts



Figure 26. A rubbing strake nailed and lashed to the outer face of the sheer strake of *kettuvallam* B. (Image: Chiara Zazzaro).



Figure 27. Stitched repair of a crack on *kettuvallam* B (Image: Alessandro Ghidoni).

up as far as the sheer strake. The short extension strakes above that level at the bow and stern are nailed, and sometimes screwed, to their respective posts, but not stitched: the nails are driven either square or obliquely and recessed. The washstrake is fastened to the sheer plank using both obliquely driven nails and sewing (Fig. 30A–B). The sewing pattern here resembles that of the hull planking, but with much larger stitches (>300 mm) and no wadding: the same type of stitching also secures the rubbing strake aft (Fig. 30A). The greater hole spacing and lack of wadding makes for

weak fastening between these elements—the builders did not require a strong bond or water-tightness here. This sewing method, also observed in the southeast Indian *masula* (Kentley, 2003a: 158), also secures the *kettuvallam*'s finials (Fig. 23).

Frame lashings

The frames of the *kettuvallam* are lashed to the hull; unlike the *baggāras*, the cordage passes through a hole drilled through the frame, instead of turning around it (Fig. 31A). The corresponding holes on the hull planks

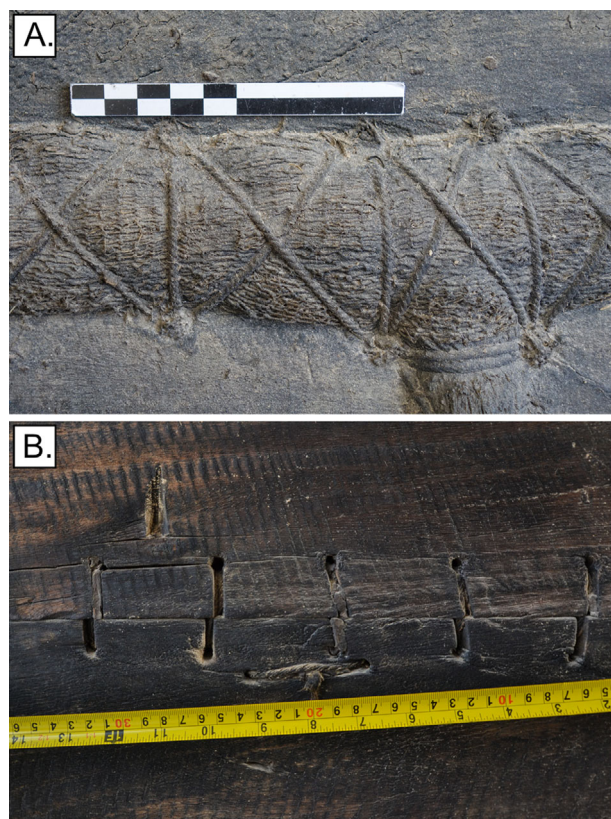


Figure 28. The sewing pattern deployed: A) inboard; and B) outboard the hull planking up to the sheer strake of *kettuvallam* B. (Images: Alessandro Ghidoni, Chiara Zazzaro).

are arranged horizontally, one on each side of the frame (Fig. 31B). These lashings are often obliquely angled—sometimes considerably—instead of being square to the hull planking as was the case with the *baggāras*. In a few cases, the futtocks, or part of a floor-timber, are lashed continuously; essentially, the cordage was not cut after each lashing, but run to the next one, though not under tension.

Discussion and conclusion

The sewn *baggāras* and *kettuvallams* of the QM collection are unique museum holdings of western Indian Ocean sewn-boat technologies. The former are extremely rare survivals of a type that is, as far as we are aware, no longer in use anywhere; while the *kettuvallams* are still in use in Kerala, they are not, to our knowledge, preserved in museum contexts elsewhere.

The *baggāras* are exceptional not only for their rarity, but also because of two particular characteristics: one is the previously undocumented technique—academically at least—of sewing both of the garboard strakes to the keel at the same time, in a single sewing action, using a single piece of cordage that crosses back and forth from port to starboard. We have hypothesized

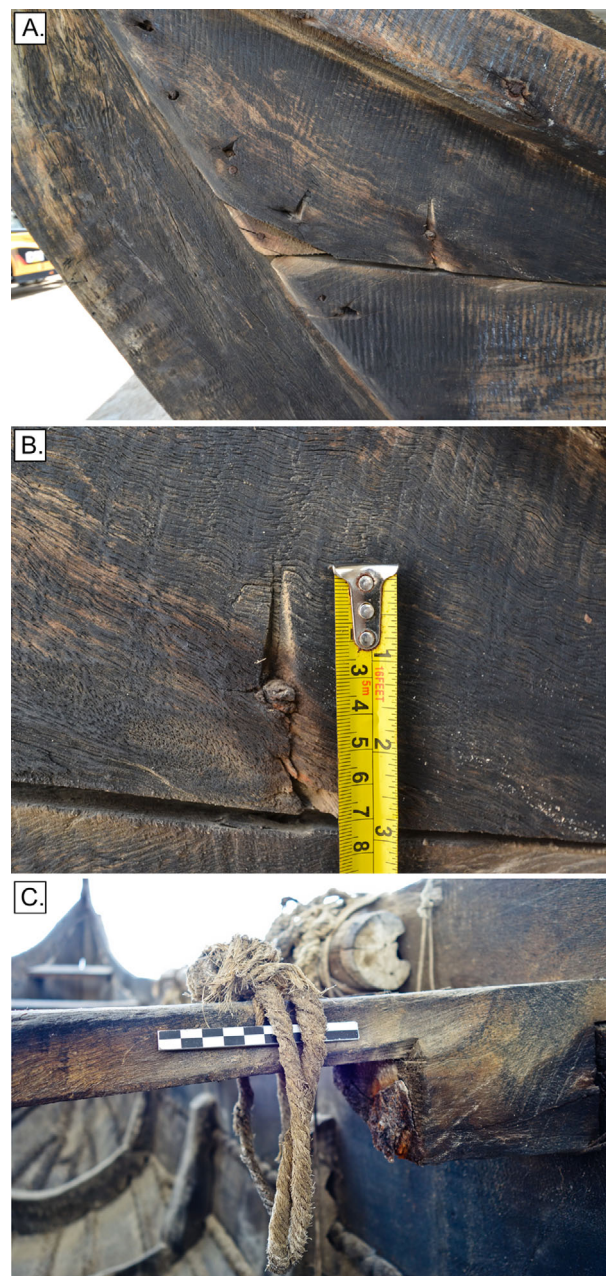


Figure 29. Metal fastenings used in the construction of *kettuvallam* B: A) nails driven square and obliquely secure the hood-ends of the extension planks to the stern post; B) close-up of one of the oblique nails edge-fastening the hull planks; C) the large rivet fixing the thwart to the hull planking and rubbing strake. (Images: Alessandro Ghidoni, Chiara Zazzaro).

a sequence for the stitching of this joint. The other is their extensive use of bitumen as a coating, both inboard and outboard, something that has hardly been noted in the modern-era boatbuilding traditions of the western Indian Ocean.

The fact that QM has acquired five examples of the *baggāra* allows an opportunity for comparison



Figure 30. The wash strake and rubbing strake fastened to the sheer strake with stitching but no wadding on *kettuvallam* B: A) outboard, the vertical stitches act as lashings threaded through holes along the rubbing strake; B) the inboard view. (Images: Alessandro Ghidoni, Chiara Zazzaro).

between individual vessels that point to the inherence of variation among vernacular watercraft, even as the builder conceives of and works towards an overall type-form. The vessels do not vary greatly from each other in principal dimensions and ratios (Table 1): keel and post assemblies are broadly similar; the builders' conceptions (though not execution) of overall planking objectives are similar; beam and deck configurations are almost identical; approaches to stitching, lashing, and the use of iron fastenings are consistent.

And yet there is plenty evidence of the hand of the individual builder in each vessel—hinting at different builders across the set. The builder of *Baggāra* 3 appears to have had the available planks and skills to keep closest to concept, achieving a high degree of uniformity and symmetry in the hull schema. The resulting form is 'full' in cross-section, with a flat garboard amidships. Its bow rakes some 3–4° more than the other vessels. The builder of *Baggāra* 1, meanwhile, showed a willingness, within the overall concept, to use joggle jointing not seen on the other vessels; the hull is less full in cross-section, with an acutely set garboard. Finally, *Baggāra* 2 stands out on several fronts: its main keel timber is proportionally longer; its aft keel

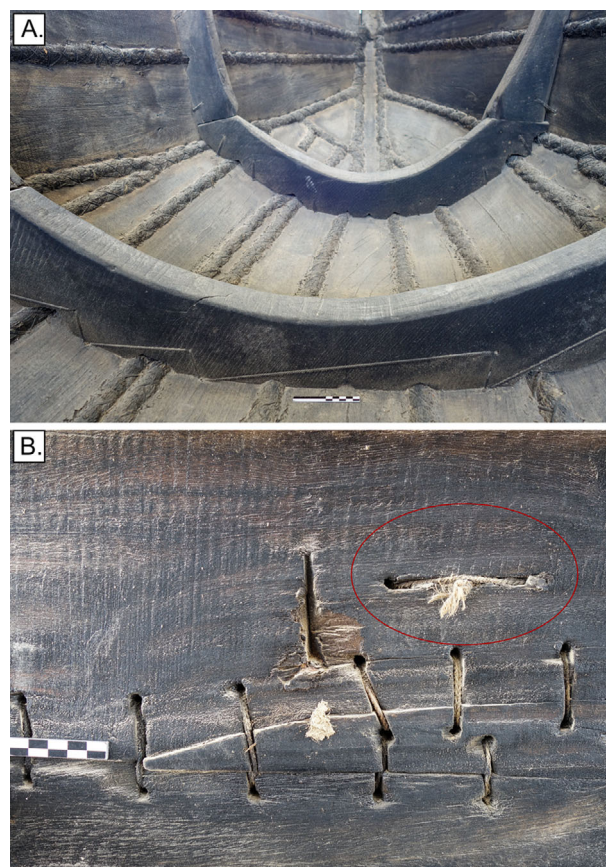


Figure 31. Frame lashings inboard on *kettuvallam* B, showing the cordage passing through holes drilled through the moulded face of the frames; A) the lashing cordage of the frame in the foreground is continuously threaded through each hole; B) the frame lashing outboard, highlighted in red. (Images: Chiara Zazzaro).

timber is 'flatter'; and it is relatively flatter bottomed than the other two. In terms of its planking plan, the deployment of a 'double-width' plank on the port side and the plethora of stealers and graving pieces might be the result of later repair, but they certainly indicate a willingness to adapt available materials to achieving the overall hull concept. Across the hulls, there is also some variety in the cordage and dowels used as fastenings, as Tables 2 and 3 show.

The *kettuvallams* are a variety of 'tied' boat that is still in use in Kerala but that has not previously been described in detail. Only one of the two vessels in the QM has been presented here. Naval-lines and construction drawings show a rather symmetrical, U-shaped hull with a highly regular planking pattern. Sewing techniques are highly regular and consistent along the seams, suggesting that the boat is not very old or was not used much. Meanwhile, the vessel shows compelling similarities with the sewing techniques found in ancient sewn boats, thereby providing an important ethnoarchaeological reference point.

Acknowledgements

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Notes

1. Formerly Agisoft Photoscan Pro.
2. No. 484, Acc. No. 1984, Location 46 G2, As 88.
3. Also referred to as 'batting' (cf Prados, 1996: 102) or 'padding' (cf Varadarajan, 1998: 61).
4. Only one of QM's *kettuvallams*, which we label *kettuvallam B*, is reported here: the two vessels are very alike.
5. A lack of data led Prins (1986: 100–110) to overlook this broad South Asian-Arabia distinction (Fenwick, 2015: 393).
6. Precisely 63% of total keel length in *baggāra* 1; 68% in 2; 66% in 3.
7. As part of the British Academy-funded *The Boat Builders of Zanzibar: Nautical Technology and Maritime Identity in a Changing World* project (Project SL-08385; 2018–19; P.I. John P. Cooper; Co.I. Lucy Blue; participant researcher Alessandro Ghidoni).
8. The colour difference might simply be a result of variable staining from the bituminous coating of the vessels.
9. We thank our anonymous peer reviewer for this observation.
10. Again, we thank our anonymous peer reviewer for these observations.
11. A sample of bitumen was also found 'in a sample of hard material adhering to a thwart beam' on the Belitung wreck (Burger *et al.*, 2010: 384), but this has not been published in detail.
12. Direct observations, made during fieldwork as part of the University of Exeter's MARES Project (2008–2012), led by Professor Dionisius A. Agius and funded by the Golden Web Foundation. Cooper also observed this boat with Dr Lucy Blue during their 2007 Yemen fieldwork as part of the University of Southampton's Indian Ocean *Hūrī* project.
13. Although, as our anonymous reviewer kindly suggests, it may always have been no more than a stylistic reference to larger, sailed vessels.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

1. 3D Photogrammetry model of *baggāra* 1.
2. 3D Photogrammetry model of *baggāra* 2.
3. 3D Photogrammetry model of *baggāra* 3.
4. 3D Photogrammetry model of *kettuvallam* B.

The research data supporting this publication are openly available from Zenodo, doi: 10.5281/zenodo.3939127