ARTISANAL BOATBUILDING IN BRAZILIAN SHORES: CRAFTSMEN, BOATYARDS, AND MANUFACTURING PROCESS

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ABSTRACT

The majority of Brazilian small craft fishing fleet comes from artisanal boatyards which struggles with market pressure, professional social devaluation, and lack of raw materials. This work aims to provide a description about small craft artisanal boatbuilding in Brazilian shores to support initiatives to increase its social, economical, and environmental sustainability. On site visits and interviews about craftsmen social-economics; boatyards' production organization; and manufacturing processes' technological aspects were conducted. Results show that craftsmen are characterized by reasonable income and livelihood degree, compared with workers of similar educational level in their region. Relationships and work organization among them is traditionally structured and community based. Boatyards have sufficient structure, though access to new technologies and resources could be increased. Observed plank on frame building technique depends on workforce skills, commitment, and knowledge, as well as the resulting boats' design and performance. Small craft artisanal boatbuilding is a living sector with its own dynamics, subjected to the creation and eventual adoption of new technologies. Instead of replacing the current manufacturing process by fibreglass reinforced polymer laminates, as suggested by some initiatives, it is believed that this sector's sustainability can be increased by gradual introduction of tools, materials, and techniques while preserving its artisanal characteristics and qualities.

KEYWORDS: *Small craft design; artisanal boatbuilding; woodworking; fishing fleets.*

I. INTRODUCTION

The majority of Brazilian small craft fleet comes from artisanal boatyards. The artisanal boatbuilder usually is a member of small-scale fishery community. These relationships allow them to develop quality and performance characteristics of their craft. In the past decades this sector struggles with market pressure (Walter, 2010), professional social devaluation (Prado, Seixas, & Berkes, 2015; Trimble & Johnson, 2013) and lack of raw materials (Braga, 2013; Pohl, 2007).
Small crafts enclose specific challenges for design and construction, e.g.: economic resources optimization (Nasseh, 2000); high level of specialized workmanship (Gerr, 1999); and specific design for sea keeping, range, and performance in reduced dimensions (Aasheim & Werenskiold, 2004). Craftsmen deal with tacit knowledge (Falck, 2014) inherited and enhanced through generations over the relationship between boat's shape, performance, materials, and manufacturing process (Carvalho, 2014). Artisanal boatyards have skilled and experienced staff while are hypothetically technologically underdeveloped and unsustainable.
Crafts are built by the so called *plank on frame* method (Castanheira, 1979; Gerr, 1999), where wood planks are laid over longitudinal frames, caulked and painted. Wood types must have high flexural strength, which is translated into high density wood. They also need to have natural resistance against maritime organisms' attacks, especially wood borers like *Teredo navalis* (Borges, 2014). Builders try

to identify resinous hardwoods suitable for boatbuilding while not valuable for other uses (e.g. construction) or foreign markets. Components such as keels, longitudinal frames, hull and deck parts require large timbers and sometimes specifically curved shapes. Wood quantity and quality raise manufacturing costs and doubts against its sustainability.

Technological enhancement initiatives (Fyson, 1991; Gulbrandsen, Food, & of the United Nations, 2012; Pohl, 2007; Roskilly, Nanda, Wang, & Chirkowski, 2008; Shamsuddin, 2003; Wibawa, Birmingham, & Woodward, 2015) usually propose the adoption of glass fibre reinforced polyester resins despite its problems with air pollutant emissions (Baley, Perrot, Davies, Bourmaud, & Grohens, 2005), toxicity (Henriks-Eckerman et al., 2015), non-renewable and non-recyclable raw materials (Singh & Wittamore, 2015), and potential water and soil pollution (Turner & Rees, 2016). There are reported experiences where new designed boats were rejected by users (Pohl, 2007) indicating a demand for careful planning over such initiatives. However, there is a lack of systematically acquired information about this complex sector, in order to support such planning.

This work aims to provide a description about craftsmen social-economics, boatyards' production organization, and manufacturing processes' technological aspects on small craft artisanal boatbuilding (SCAB) in Brazilian shores to support initiatives to increase its social, economical, and environmental sustainability.

II. METHODOLOGY

An object-study approach was conducted over past years with bibliographic materials, sporadic visits, and photographic registered non-structured interviews at artisanal boatyards in: Navegantes/SC, Balneário Barra do Sul/SC, Florianópolis/SC, Guaraqueçaba/PR, Pontal do Paraná/PR, Fortaleza/CE, and Acaraú/CE; as well as the *Museu Nacional do Mar* (National Sea Museum, MNM) collection of traditional boats and boats' models at São Francisco do Sul/SC. Such visits allowed to understand the artisanal boatbuilding sector characteristics, recognize boats' traditional shapes, uses, and manufacturing techniques.

From 2012 to 2013 a systematic survey on SCAB aspects was conducted over the coastal region from São Mateus/ES to Santa Cruz Cabrália/BA. Over those 8 municipalities, structured interviews were conducted on social-economic and manufacturing process aspects with 42 craftsmen including masters, shipwrights, mechanics, electricians, painters, and caulkers. Social-economic survey identified regional SCAB craftsmen's profiles in order to know their characteristics about: (i) social origin; (ii) income levels; (iii) labor situation; and (iv) expectations about artisanal boatbuilding. General description of manufacturing process allowed to describe the work environment (the yard), the final product (the boats), and their building process.

In order to compare regional process differences and to fulfil information that cannot be achieved with sporadic interviews, a 13,5m length boat construction was watched from year 2013 to 2015 at an artisanal boatyard in Balneário Barra do Sul/SC. Boatyard's visits periods allowed observation of day-to-day ground work, as well as details and specific manufacturing techniques clarification.

Twenty fishermen communities in Bahia State were visited during two field trips in 2013 in order to record boatyards' location, their structure and applied techniques; as well as fishermen perceptions on boats performance and fishing fleet composition. In such manner, two main artisanal boatbuilding regions from Brazilian shore were totally covered (Santa Catarina and Bahia). Maranhão and Ceará States' coast were compared through bibliographical information (Andrès, 1998; Braga, 2013).

III. RESULTS AND DISCUSSION

The most common uses for artisanal boats were identified as: transport, tourism, sports and leisure, specialized work, and fishery. Main SCAB market is fishing craft. More than 99% of marine 60,000 fishing vessels fleet in Brazil are less than 24m length, with most significant part composed of artisanal built tiny undecked craft, small, and medium sized boats (PROZEE/SEAP/IBAMA, 2006). Those figures are almost the same for other developing countries (FAO, 2016).

3.1 Craftsmen and boatyards

Artisanal boatyards' staff are identified as master builders (or just *master*), naval carpenters or shipwrights (also called *officers*), assistants, and apprentices. It was observed a majority of masculine workers and that female role, if any, was restricted to assistance and administrative activities, usually by masters' wives or daughters.

The master builder is responsible for: sales, service contracts, hull shape design (also called *scratch*), boat scantlings and subsystems sizing, day work management, raw materials and supplies acquisition, machinery and tools acquisition and maintenance schedule, boatyard layout, monitoring of critical building steps, and financial management. They are also characterized by knowledge transmission and training of the other workers (Gomes-Dias, 2014). Boatyards are recognized by its master's name, even if they have a trade name, which is also associated to boat quality and performance. Masters also assign other craftsmen working categories and career evolution (e.g. from assistant to shipwright).

Shipwrights are those who carry out the building activities, from component manufacture to assembly. They are guided by their master, and must be able to conduct every construction step to be called an officer, even if they have preference or greater aptitude for some kind of work, like structural construction, cabinet making or finishing. They can also be responsible for machinery maintenance, mainly tool sharpening. Shipwrights train assistants and apprentices and, to some degree, manage their daily tasks. In some regions shipwrights and officers are distinguished among those latter with higher status and abilities to conduct crucial steps without a master's assistance (e.g. keel parts joining; stern or bow construction).

One or two craftsmen assist each shipwright on handling of material and components; doing general tasks as cutting, drilling or fastening; and housekeeping. Young fellows or professionals from other sectors (e.g. construction) begins their activities as assistants and are gradually instructed and supervised by shipwrights and master builders.

Kinship relations between masters, shipwrights, assistants, and apprentices are very usual. Such relationships often extend to god-parenting each other's marriage or children baptism.

Wages are calculated by day of work and paid fortnightly or monthly. Shipwrights' observed incomes range between 2 and 3 minimum wages. Assistants' wages are 20 to 30% lower than the shipwrights'. Apprentices' payment ranges from half to equal that of assistants. Masters take to themselves the same or a slightly superior amount of the shipwrights' wage; and they manage eventual profits at boat launching between personal gain and yard investments. Masters often offer advance payments or assume financial responsibilities of their workers, such as the purchase of medication, supplies or vehicle financing.

Most interviewed SCAB craftsmen are members of C and B social classes, have their own masonry house with four or five rooms, stable family situation, and access to services such as water supply, waste-water and waste collection, electricity, indoors bathroom, and public education and health system. The activity is characterized by high informality degree (over 80% of workers do not have a formal contract) and low social security (50% of respondents do not collect social insurance taxes). With few exceptions, craftsmen recognize themselves and are recognized by fishermen as members of the fishery production chain and plead its category retirement system while still remaining active even at 65 years-old and older.

It's a unanimous complaint that there is low labor renewal and therefore difficulty to transmit knowledge to new generations both among interviewees and in literature (Andrès, 1998; Braga, 2013; Castro & Gomes-Dias, 2015; Fogaça & Franci, 2012; Gomes-Dias, 2014). A similar condition is observed in artisanal fisheries where there is an increasing competition for labor generated by other activities at the same territories (e.g. tourism or oil exploration) (Walter, 2010), including shipyards. However, field observations pointed that one fifth of the working force is composed of teenagers (from 15 to 24 years) and young adults (25 to 34 years). Moreover, fishermen and boat builders reported that contract demand for new building jobs, refits, and maintenance services are beyond the boatyards' capacity. Thus, it is believed that low and medium sized artisanal boatbuilding, even in decline and in need of strengthening initiatives, is not an endangered sector. Such evidence should not be stated for canoe (especially log canoes) builders, whose masters from several localities are in very advanced ages and have no apprentices (Denadai, Gonçalves, Olivato, & Turra, 2009; Lanziotti, 2010).

Masters coordinate and sometimes subcontract services from caulkers, painters, lettering and sign painters, electricians, and mechanics. Caulkers are responsible for water tightness between hull and deck planks. Such activity is quite repetitive and physically exhausting, requiring specific skills. Caulkers work alone, with one partner or a small crew and can be paid daily or under contract. In general, their incomes are equal to those of assistants. Painters are paid in the same range as are the shipwrights.

Their work can be specialized in upper works or hull painting. The latter can also be split into surface preparation (filling and sanding) and multilayer anti-fouling coating system application (sealant, primer and anti-fouling). Name and vessel registration number painting are performed by specialized professionals, called 'lettering painter', working by contract.

Electricians and mechanics are small business or self-employed professionals servicing local or regional boatyards on subsystem sizing, materials and parts' supply, installation, test and improvement. Engine's model, power and installation, shaft dimensions, rudders, and other subsystem characteristics are defined in conjunction by mechanics, masters and shipwrights and often lead to disagreement and conflicts.

With the exception of mechanics and electricians that hold a vocational degree, SCAB craftsmen education level is similar to their region low-income workers, i.e. complete or incomplete elementary school for older workers and complete or incomplete secondary school for younger ones (such age differentiation is probably a result of the expansion regarding primary and secondary education in Brazil over the last two decades).

Boatyards' structures are similar across different regions. On most cases, yard land is owned by the master builder and is attached to or is near his residence (however, sometimes craft work is done on public spaces, like beaches and waterfronts). Those are usually open spaces with access to a watercourse, partially covered by fibre-cement roofs over wooden structures. Roofs are used for machinery protection and, in a few cases, cover the boatbuilding area.

Boatyards usually deal with one to four orders, sometimes reaching six crafts simultaneously being built. An area around 100 to 200m^2 is dedicated for each craft. Waterfront is dedicated to boat maintenance services or almost concluded projects. Planks, logs, parts and even boats must be handled over the yard without lifting mechanized equipment. There is a broad use of rollers, pulleys, chain hoists, hydraulic and house jacks. Some yards have water ramps, towing carts and electric winches.

Most of the observed power tools are for woodwork: table saw, large band saw, thickness planer, and jointers. In some cases there is also: reciprocating saw, table router, grinder, bench or table drilling machines, table belt sander, and air compressor. Such equipment must be tough enough to hold large timber components. According to the artisans, currently available machines are not suitable for that purpose. Thus, masters maintain or acquire and restore old industrial woodwork power tools.

Observed electrical powered portable tools were: circular saw, jig saw, plane, drilling machine, and rotating angular sander. Less frequent are: orbital sanders, screwdrivers, and chainsaws. Pneumatic tools were not observed. Observed hand tools were hammers, mallets, handsaws, wrenches, screwdrivers, chisels, planes, braces, brushes and rollers, gimlets and augers, and flat and gouges adzes. Measuring instruments are basically folding meter and measuring tape, accompanied by the shipwright's compass, scratch awl, squares, bubble level, and sliding T bevel. Caulking is done with caulking irons and mallets. Workbenches are generally in a few number. It is common for workers to perform tasks within the boats, on the ground or with the aid of easels. As the vessel takes shape and size, ladders, trestles and scaffolding are built around it.

The proportion between maintenance services and new builds are influenced by the fisheries' local economic situation. Where fishing activities reach positive economic results, there are contracts for new boats all year-round and maintenance services are concentrated during closed seasons, reaching 30% of annual revenues. Where fishery is declining or new fishing licenses are not emitted, maintenance services reach 80% or even total of annual revenues.

Artisanal boats are ordered by contract and specified by size or length (usually length at waterline, LWL), traditional shape, purpose, engine model and power. Usually the contract deal is closed with payment in advance for wood acquisition, followed by instalments on manufacturing stages (e.g. finished structure, planked hull, finished upper works, and so on). The construction of boats ranging from 9 to 12 meters in length usually takes from 6 to 12 months, with up to 12 more months for installation of subsystems. Some master builders start new craft constructions on their own expenses to keep the workforce active during low demand seasons.

Although they do not use technical drawing as a communication support, artisanal boatbuilders articulate several elements and subsystems in order to design the craft. From engine power and LWL, master and boat owner agree on propeller diameter, which defines shaft log, draft and keel size, and proportionally sizes bow and beam. With this set of parameters masters are able to communicate scantlings for other craftsmen and order raw materials from their suppliers. They are also able to preview the boat's final characteristics (cargo capacity, fish hold overall dimensions, freeboard, waterline position, displacement) and to estimate the amount and quality of raw materials.

Craft general dimensions, proportions and scantlings are tacit inherited and enhanced knowledge. Thus, resulting shape vary between different masters and are recognized (and protected) as their creation and property. In some cases those proportions are expressed on plywood models of amidships and bow transversal frames. Such models are manufactured for a range of vessels' sizes and handled only by masters and designated officers. Another way of proportion registry observed in field research is the *graminhos*, an ancient heritage used for Saveiro's construction, as described by Castro & Gomes-Dias (2015).

3.2 Observed manufacturing processes

In order to identify SCAB bottlenecks and capabilities, current manufacturing processes for small and medium sized crafts (from 9 to 24 meters length) is presented as a general description of the process followed by detailing of some key steps, some relevant parameters discussion, and technological changes currently in progress.

SCAB manufacturing process in Brazilian shore is mainly *plank on frame*. It consists of building a three dimensional wooden framework, over which hull and deck planks are attached. For each component the process can be divided into measure, part manufacture, and part assembly.

Fig. 1 schematically represents construction steps. Keel manufacturing and levelling (a) is followed by (b) transom and (c) bow assembly. Patterns, moulds, proportions or *graminhos* are used to manufacture a few references transversal frames, usually around amidships (d). Flexible wooden battens are fixed from bow to stern at different heights (waterline planes), composing a three dimensional set of guidelines (e). The remaining longitudinal reference is measured, manufactured and assembled (f) and then keelson (g) is fixed. Deck beams (h) and stringers (i) give stiffness to the spatial structure, which receives deck (j) and hull (k) planks. Some steps can be executed in distinct sequences.

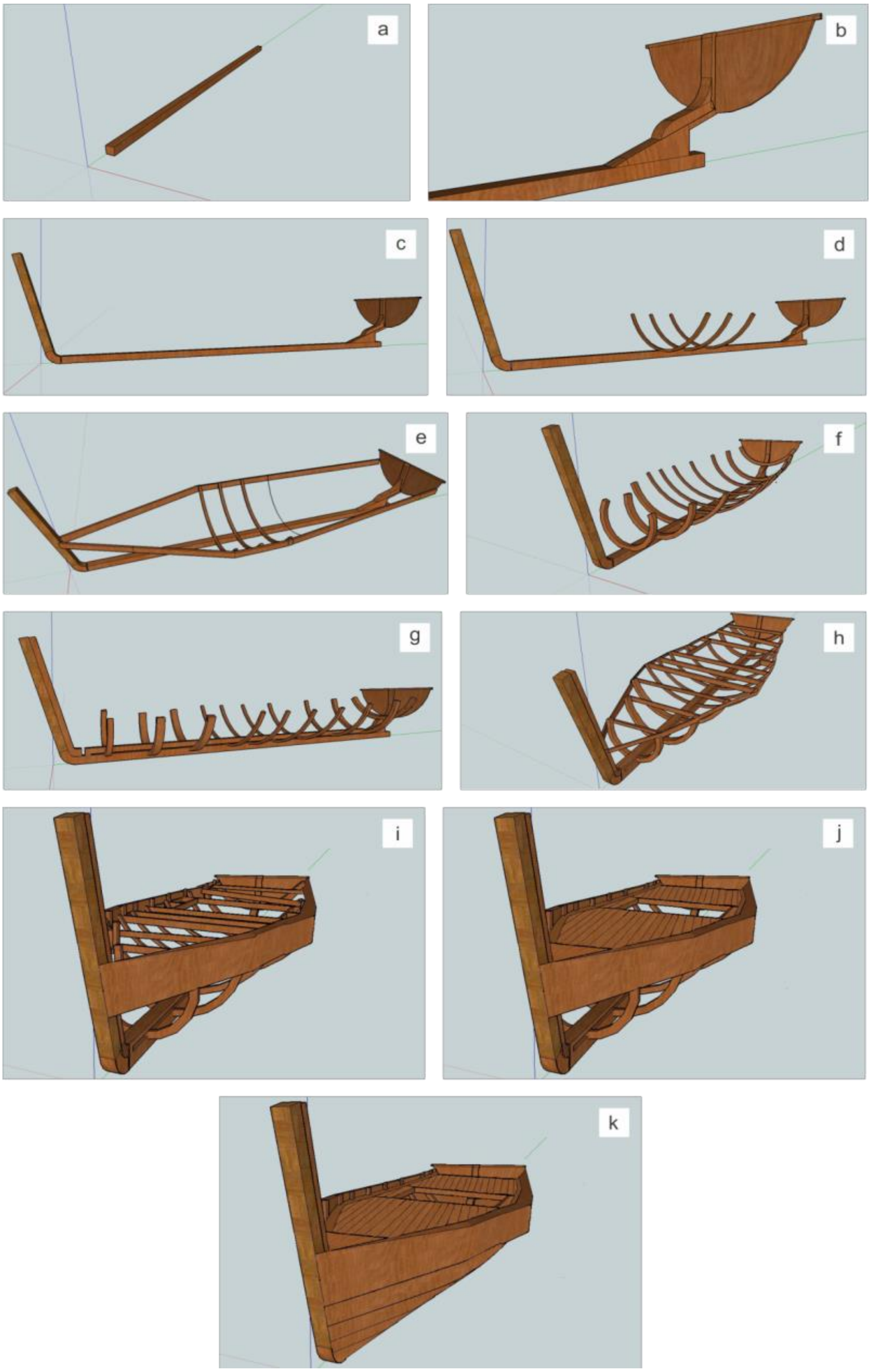

Fig. 1: Schematic representation of traditional plank on frame boatbuilding stages: (a) keel, (b) transom, (c) bow, (d) reference longitudinal frames, (e) deck batten and ribband, (f) remaining longitudinals, (g) keelson, (h) deck beams, (i) stringer, (j) deck and (k) hull planks.

Master builders give special attention to design and build of shaft logs. In Fig. 2a and 2b a solid wooden component is carved to admit a 90cm diameter propeller. The upper slope will define stern angle, while base width must fit keel dimensions and its curved sides will interfere the water flow around the propeller. In this case, keel is being built in two segments. Rear component is attached to shaft log (Fig. 2c) and forward to bow (Fig. 2d). The notched line indicates where bottom planks will lay (Fig. 2e). Keel components are mechanically joined (Fig. 2f) and bolted.

Fig. 2: Structural initial elements of a traditional boat. Shaft log rear (a) and side (b) view, rear (c) and forward (d) keel components, shaft log bolted to stern keel (e), and keel components junction (f).

These elements will be joined, positioned, and levelled. From a rear view (Fig. 3a) stern keel, shaft log, keel and some reference transversal frames can be seen. The latter constitutes an almost prismatic section amidships from mentioned proportions (in section 3.1). From amidships to bow, reference battens were positioned into six waterline planes (Fig. 3b) and used to create longitudinal plywood made (white) patterns (Fig. 3c). Keel is carved and bevelled to receive longitudinal frames and hull planks (Fig. 3d).

Fig. 3: Battens and reference longitudinal frames. Stern view (a), bow view (b), battens and patterns detail (c), and carved and bevelled keel (d).

In Fig. 4a longitudinals are fully assembled for a 13,5m LOA craft. Deck line batten and chine plank can be seen. The chine plank is placed between hull sides and bottom and is the reference for planking from chine to deck line (Fig. 4b) or from chine to keel (Fig. 4f). Simple bent or smooth compound curved planks are clamped in place, drilled, countersunk, and nailed. Nails are hot-dip galvanized steel. Drilling avoids wood from splitting. Plank and keel must be joined into bevelled surfaces (Fig. 4c) to allow proper caulking. Compound curved surfaced planks must be heat-softened and bent. This can be done with a fire torch or steam chamber (Fig. 4d) and clamped to bend on place (Fig. 4e).

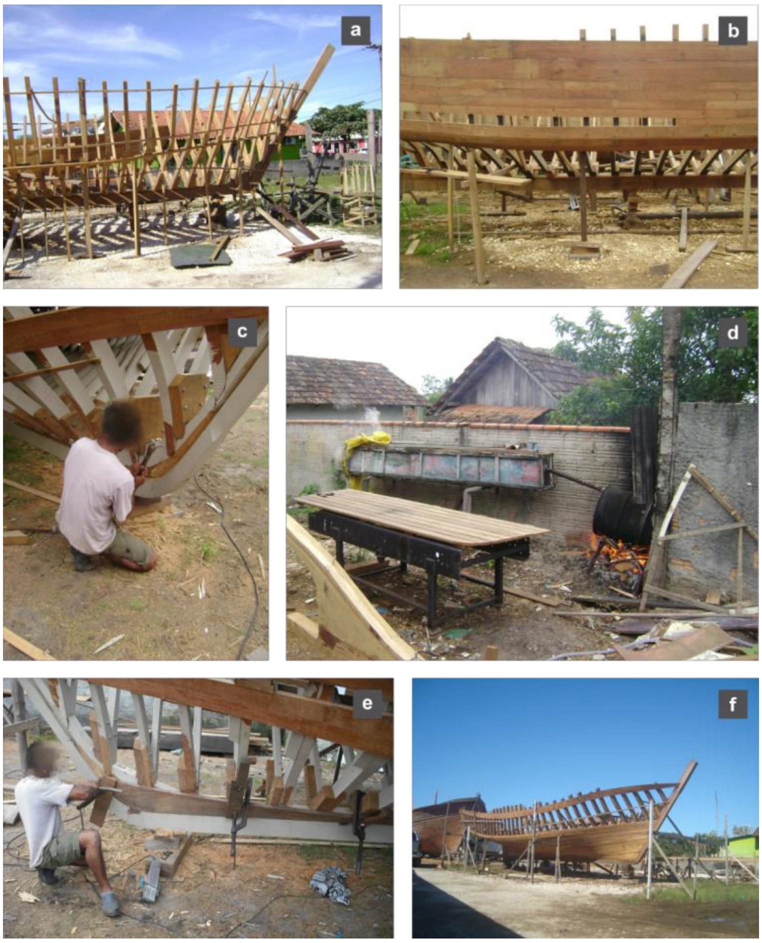

Fig. 4: Planking. Longitudinals (a), hull side (b), carving bow (c), steam chamber device (d), plank clamping (e), and hull bottom (f).

Cabin is build with plywood sheet walls nailed over wooden structures. Cabin spatial configuration depends on the intended craft use. Its overall dimensions express compromise between required internal space and the wind influence over the exposed area above deck on seaworthiness.Cabin's external plywood sheets sides are laminated with fibreglass reinforced polyester for increased weather resistance (Fig. 5). Plywood is impregnated with catalysed polyester using wool rollers, over which are laid layers of woven fibreglass or fibreglass mats. Impregnation is completed with another coat of polyester (Fig. 5a). After pre-curing time at room temperature, the resulting composite is gel-coated (Fig. 5b). All considered *wet* areas, such as toilets, ice boxes, fish hold chambers, bilge covers etc. are usually sheathed.

Planked hull is caulked with cellulose fibres which expands with water uptake and, in conjunction with wooden swelling, makes the craft watertight. Caulking materials can be locally extracted fibres (e.g. from Biriba, *Rollinia mucosa*) or cotton. Filling compound is usually *spackling* paste (vinyl resin with mineral fillers and thickeners, according to producer data-sheet) or automotive body filler (alkyd resin with mineral fillers and thickeners, according to producer data-sheet). Hull's planks must be sanded to promote a smooth and even surface. Sanding operation starts with angle grinder and 20 or 36 grit grinder discs. Eventually a sanding step with grit 80 grinder discs is done and considered as finishing grade. It should be noticed that angle grinders are not adequate for such operation, as craftsman cannot control material removal to produce a fair surface. Shipwrights reported that sanding blocks and boars were used to be common practice to such operation. However, sanding blocks and boars were substituted by electrically powered angle grinders because of their working speed. It is an overhead operation, dealing with heavy equipment, large amounts of sawdust and large compound curved surfaces. Hull sanding is exhausting, dangerous, and requires skilled labor to achieve the desired results. It is considered among artisanal boatbuilders the main skill of a boat painter.

Fig. 5: Fibreglass reinforced polyester plywood coating. (a) Fibreglass woven polyester impregnation, and (b) applied gel coat.

The hull is then washed and waterline is placed with tack tape under the master builder's supervision. Above the waterline, the hull will receive primer and alkyd coatings. According to shipwrights, some species of wood (e.g. *Dipteryx odorata*, named Ipê Champagne or Cumarú) produces colour changes to coatings (due to extractives migration), which can be avoided by using a primer coat. Bulwark was coated with an impregnating finish stain. According to the manufacturer's data sheet, it is composed of fungicide, alkyd resin, vegetable oils, water-repellent, pigments, additives, and aliphatic solvents. Cabin fibreglass coated surfaces receive adhesion primer (epoxy primer isocyanate aliphatic two-component low thickness, according to the supplier's technical data sheet) and alkyd coating.

Bottom hull coating system consists of: (Fig. 6a) dual component polyamide epoxy primer with high solids content and coal tar, (Fig. 6b) anti-corrosive coal tar free vinyl coating, and (Fig. 6c) soluble matrix anti-fouling paint. Over coating intervals must be observed for each application. If the coating is applied before the recommended lower interval, it is likely the occurrence of drying and curing problems; while applications made after the upper interval limit will promote adhesion deficiency between layers. There is also the need of an interval before painting flooding, i.e. between boat finishing (Fig. 6d) and launching. The intervals of the paint system require planning and stable weather conditions. Launching a new boat usually requires a workforce gathered outside the yard. It is a sensational event, usually followed by celebration among craftsmen, fishermen, boat owners, and community fellows.

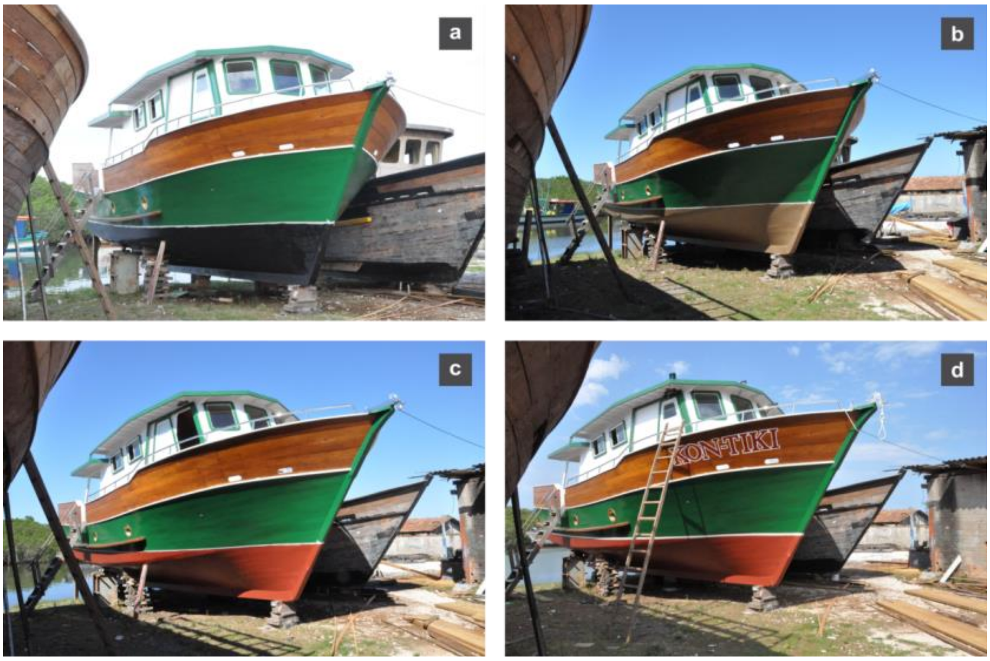

Fig. 6: Hull bottom coating. (a) Epoxy coal tar prime, (b) coal tar free vinyl coating, (c) anti-fouling paint, and (d) finished craft.

3.3 Ongoing changes

Comparing the observed practice and techniques applied in boatbuilding with traditional boatbuilding literature (Andrès, 1998; Braga, 2013; Castanheira, 1979; Castro & Gomes-Dias, 2015; Gerr, 1999, 2001; Lowell, 2002), as well as noticing the ongoing changes reported by the interviewees, allow for the understanding of technological gaps and enhancements in SCAB. Such changes were organized according to their relation to the boat's shape, the manufacturing process, and raw materials selection.
River or estuary depth reduction due to siltation processes is the main reported reason for traditional craft shape modification in order to reduce draft. Such modifications include the adoption of 4, 5 or even 6 bladed propellers (compensating diameter reduction); lateral stabilizers' installation; and stainless steel reinforcement plates on keels.
In relation to the manufacturing process, it is observed the adoption of electrically powered portable tools and chainsaws, due to their lowering prices and increasing availability in the Brazilian market. In some cases, artisanal boatbuilders are adopting composite related techniques, particularly hand lay-up methods.
Although several wood species are reported to be applied on artisanal boatbuilding in bibliographic references and by craftsmen (Ipê, Oiticica, Angelim, etc.), it was observed the almost unanimous adoption of Garapeira (*Apuleia leiocarpa*) throughout the visited boatyards. In recent years, south region's boatyards have also begun to use Cumaru (*Dipteryx odorata*), and the boatbuilders from the northeaster coast have been choosing Jaqueira (*Artocarpus Interglifolia*) as substitutes for the Garapeira. Plywood is largely applied for the construction of the cabin and internal parts, with or without the related fibreglass sheathing process described in section 3.2. Internal components may also be made of *demolition wood*, i.e. wood acquired from demolished houses, e.g. for cabin's flooring and cabinet making.
High degree of waste and poor take of wooden logs and planks is usually associated to SCAB. Notwithstanding, it was observed that wood scraps are stacked by craftsmen according to their size and quality to be used as reference rules, patterns and battens; as stanchions, ladders and scaffoldings; and for manufacturing of smaller boat components, including those in maintenance by fishermen outside the boatyard. Useless scraps are burned in steam chamber devices (Fig. 4d) or at locals' wooden burning stoves and ovens. Saw dust is regularly collected by local farmers to be used as forage or fertilizer. In exchange, craftsmen receive "gifts" such as fish, vegetables, charcoal, etc. On the other hand, other materials' (e.g. fibreglass and paint) waste disposal could be improved.
Filling compounds have been substituted by polyurethane sealant adhesives. *Nautical glue*, i.e. dual component epoxy adhesives is also widely employed, with or without sawdust filling. In one case, a locally developed technique to coat the hull and protect it against wood borers' attacks employs *nautical glue* filled with sawdust, mortar and *spackling* paste. With the same objective, some builders are sheathing hulls with fibreglass reinforced polyester.
Such changes are conducted by the boatbuilders in an attempt to improve their processes and products. However, it is clear the lack of technical and scientific support, which may incur in misunderstandings with losses for both artisans and their customers. For instance, hull sheathing with fibreglass reinforced polyester will probably delaminate due to poor bonding in the polyester/wood interface caused by extractives migration (the same phenomenon aforementioned for colour changes, section 3.2). The gap between wood and fibreglass sheet can retain humidity, which will lead to a process of decay that could be noticed only when the hull is severely rotten.

IV. FINAL REMARKS

Generally described only from the perspective of its traditional materials, processes and shapes, small craft artisanal boatbuilding is a living sector with its own dynamics, subject to the creation and eventual adoption of new technologies.
SCAB craftsmen are characterized by a reasonable level of income and livelihood, when compared to workers of similar educational level in their region. Relationships and work organization among them is traditionally structured and community based. Artisans show environmental concern regarding their activities and usually adopt sustainable attitudes, such as wooden scrap and sawdust reuse described in section 3.3. Tools such as pneumatic nail guns, fairing boards and sanders, airless painting equipment,

modern drill bits; material handling devices; and sheds could increase safety and healthy working conditions while reducing manufacturing time and cost.

To better understand traditional boat shapes and their relation to performance, further research is being conducted on three-dimensional digitization registry of hulls for further analysis via naval architecture software and small craft design principles.

Small craft artisanal boatbuilding can be highly affected by the introduction of other materials and manufacturing processes, like composites or metal alloys, including issues related to expertise acquisition. Further research is being conducted in order to systematically compare those against traditional materials, reforested wood, and alternative wood species, according to Design & Materials Selection methodologies presented by Ashby & Johnson (2014).

Instead of completely changing manufacturing processes from wooden to fibreglass reinforced polymer construction, as suggested by the initiatives mentioned in section 1, it is believed that the selection and eventual introduction of tools, materials, and techniques must consider this sector's artisanal characteristics of articulation of knowledge and social organization, as well as the boats' performance, aesthetics, and meaning characteristics.

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REFERENCES

[1]. Aasheim, I., & Werenskiold, P. (2004). Application of IMO HSC Standards For Small Craft. *The International Journal of Small Craft Technology*, *146*(b2), 15. https://doi.org/10.3940/rina.ijsct.2004.b2.3404

[2]. Andrès, L. P. de C. C. (1998). *Embarcações do Maranhão: recuperação das técnicas construtivas tradicionais populares*. São Paulo: Audichromo Editora.

[3]. Ashby, M., & Johnson, K. (2014). *Materials and Design*. *Materials and Design*. Burlington: Butterworth-Heinemann. https://doi.org/10.1016/B978-0-08-098205-2.00010-X

[4]. Baley, C., Perrot, Y., Davies, P., Bourmaud, A., & Grohens, Y. (2005). Mechanical Properties of Composites Based on Low Styrene Emission Polyester Resins for Marine Applications. *Applied Composite Materials*, *13*(1), 1–22. https://doi.org/10.1007/s10443-005-9000-9

[5]. Borges, L. M. S. (2014). Biodegradation of wood exposed in the marine environment: Evaluation of the hazard posed by marine wood-borers in fifteen European sites. *International Biodeterioration & Biodegradation*, *96*, 97–104. https://doi.org/10.1016/j.ibiod.2014.10.003

[6]. Braga, M. S. D. C. (2013). *Embarcações à Vela do Litoral do Estado do Ceará - Construção, Construtores, Navegação e Aspectos Pesqueiros*. Universidade Federal do Ceará.

[7]. Carvalho, F. da P. (2014). Os Dhow do Zanzibar: A técnica de construção de uma antiga embarcação de origem árabe e o seu papel socioeconómico na actualidade. *Cadernos de Estudos Africanos*, *27*, 149–170. https://doi.org/10.4000/cea.1535

[8]. Castanheira, E. (1979). *Construção de pequenas embarcações* (2nd ed.). Lisboa: DINALIVRO.

[9]. Castro, F., & Gomes-Dias, D. (2015). Moulds, Graminhos and Ribbands: a pilot study of the construction of saveiros in Valença and the Baía de Todos os Santos area, Brazil. *International Journal of Nautical Archaeology*, *44*(1), 1–13. https://doi.org/10.1111/1095-9270.12086

[10]. Denadai, M. R., Gonçalves, M. A. O., Olivato, D., & Turra, A. (2009). *Com quantas memórias se faz uma canoa: a cultura do uso e feitio das canoas de "um só pau" no município de Ubatuba, SP*. São Paulo: Edição do Autor.

[11]. Falck, W. E. (2014). Boats and Boatbuilding in Tanzania (Dar-es-Salaam and Zanzibar). *International Journal of Nautical Archaeology*, *43*(1), 162–173. https://doi.org/10.1111/1095-9270.12049

[12]. FAO. (2016). *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all.* Rome.

[13]. Fogaça, E., & Franci, N. (2012). *A Jangada de Raiz* (1st ed.). Curitiba: Autores Paranaenses.

[14]. Fyson, J. F. (1991). Fishing boat designs: 3 Small Trawlers. *FAO Fisheries Technical Paper*, *188*, 51.

[15]. Gerr, D. (1999). *The Elements of Boat Strength: for builders, designers, and owners*. Camden: International Marine.

[16]. Gerr, D. (2001). *The Propeller Handbook: The Complete Reference for Choosing, Installing, and Understanding Boat Propellers* (Reprint). New York: McGraw-Hill Education.

[17]. Gomes-Dias, D. (2014). Sheltered Bays: Linguistic and ethnographic approach to maritime communities of Bahia-Brazil. In S. Tripati (Ed.), *Maritime Contacts of the Past: Deciphering Connections amongst communities* (1st ed., pp. 627–640). New Delhi: Delta Book World.

[18]. Gulbrandsen, Ø., Food, & of the United Nations, A. O. (2012). *Fuel Savings for Small Fishing Vessels: A Manual*. Food and Agriculture Organization of the United Nations. Retrieved from https://books.google.com.br/books?id=JlMRlQEACAAJ

[19]. Henriks-Eckerman, M.-L., Mäkelä, E. A., Laitinen, J., Ylinen, K., Suuronen, K., Vuokko, A., & Sauni, R. (2015). Role of dermal exposure in systemic intake of methylenediphenyl diisocyanate (MDI) among construction and boat building workers. *Toxicology Letters*, *232*(3), 595–600. https://doi.org/10.1016/j.toxlet.2014.12.012

[20]. Lanziotti, M. (2010). Tipologia da Canoa Monóxila do Estado de Santa Catarina. In *23o Congresso Nacional de Transporte Aquaviário, Construção Naval e Offshore*. Rio de Janeiro: SOBENA.

[21]. Lowell, R. (2002). *Boatbuilding Down East: How Lobsterboats Are Built* (2nd ed.). Washington: The Woodrow Wilson Center Press.

[22]. Nasseh, J. (2000). *Manual de Construção de Barcos* (2nd ed.). Rio de Janeiro: Booklook.

[23]. Pohl, H. (2007). From the kattumaram to the Fibre-Teppa - Changes in boatbuilding traditions on India's east coast. *International Journal of Nautical Archaeology*, *36*, 382–408. https://doi.org/10.1111/j.1095-9270.2006.00134.x

[24]. Prado, D. S., Seixas, C. S., & Berkes, F. (2015). Looking back and looking forward: Exploring livelihood change and resilience building in a Brazilian coastal community. *Ocean & Coastal Management*, *113*, 29–37. https://doi.org/10.1016/j.ocecoaman.2015.05.018

[25]. PROZEE/SEAP/IBAMA, F. (2006). *Monitoramento da Atividade Pesqueira no Litoral do Brasil – Relatório Técnico Final*. Tamandaré.

[26]. Roskilly, A. P., Nanda, S. K., Wang, Y. D., & Chirkowski, J. (2008). The performance and the gaseous emissions of two small marine craft diesel engines fuelled with biodiesel. *Applied Thermal Engineering*, *28*(8–9), 872–880. https://doi.org/10.1016/j.applthermaleng.2007.07.007

[27]. Shamsuddin, M. Z. bin. (2003). *A conceptual design of a fibre reinforced plastic fishing boat for traditional fisheries in malaysia*. *UNU - Fisheries Training Program*. The United Nations University, Reykjavik.

[28]. Singh, M. M., & Wittamore, K. (2015). Disposal of composite boats and other marine composites. In J. Graham-Jones & J. Summerscales (Eds.), *Marine Applications of Advanced Fibre-Reinforced Composites* (pp. 185–213). Sawston: Woodhead Publishing Ltd. https://doi.org/10.1016/B978-1-78242-250-1.00008-9

[29]. Trimble, M., & Johnson, D. (2013). Artisanal fishing as an undesirable way of life? The implications for governance of fishers' wellbeing aspirations in coastal Uruguay and southeastern Brazil. *Marine Policy*, *37*, 37–44. https://doi.org/10.1016/j.marpol.2012.04.002

[30]. Turner, A., & Rees, A. (2016). The environmental impacts and health hazards of abandoned boats in estuaries. *Regional Studies in Marine Science*, *6*, 75–82. https://doi.org/10.1016/j.rsma.2016.03.013

[31]. Walter, T. (2010). *Novos Usos e Novos Mercados: Qual sua influência na dinâmica da cadeia produtiva dos frutos do mar oriundos da pesca artesanal?* Universidade Federal Rural do Rio de Janeiro, Seropédica.

[32]. Wibawa, P. A., Birmingham, R. W., & Woodward, M. D. (2015). Design of Sustainable Fishing Vessels, Future Challenges for the Indonesian Fisheries. In *12th International Marine Design Conference* (Vol. 3, pp. 357–367). Tokyo: IMDC 2015.