Inventory of wooden ship materials and determination of its alternative materials through wood properties approach: case studies in the Riau islands, the northern and southern Coast of Java

L M Dewi*, R Damayanti and M Muslich

Forest Products Research and Development, Ministry of Environment and Forestry, Bogor, 16610, Indonesia

*E-mail: lizthya@gmail.com

Abstract. Indonesia is an archipelago country with approximately two-thirds of its territory consisting of oceans, so that inter-islands transportation has become one of the most important economic aspects. Traditional wooden ships are commonly used by local people in the coastal areas for transportation to support their needs. Several wood species which have high durability are commonly used for making wooden ship component such as *Eusideroxylon zwageri* (ulin), *Vitex* sp. (laban), *Tectona grandis* (teak), and *Instia bijuga* (merbau). This study aims to determine the alternative materials for wooden ship based on inventory at the Riau islands, the Northern and Southern Coast of Java. Exploring the alternative materials for wooden ship is important to optimize the utilization of lesser- and least-known timbers and address the problem of decreasing supply of major commercial timbers. This study has identified many wood species used by coastal fishermen for making wooden ship. Identification of wood species was carried out using microscopic observation based on IAWA standard, while the determination of alternative materials was undertaken through wood properties approach. The results show that there were various wood species used as raw materials for ship components. Some identified wood species are *Tectona grandis* (teak), *Shorea* sp. (balau and light-red meranti), *Dichrostachys cinerea* (pung), *Ormocia subseraceae* (kupang), *Lumnitzera littorela* (teruntum), *Alseodaphne* sp. (medang). Several alternative wood species to substitute current materials are elaborated in the paper.

1. Introduction

As maritime country with the largest archipelago in the world, inter-island transportation has become an important aspect to support economic growth in Indonesia. Adequate infrastructure is required to support water transportation to connect people from one island to another. Traditional wooden ships have been used for long time by people in the coastal areas to fulfil their basic needs. The selection of wood species for shipping to date is still based on practical experience and prevailing traditions among fishermen. The selected wood species are generally limited to several wood species that are well known in practice and have proven their superiority for shipping such as *Eusideroxylon zwageri* (ulin), *Vitex* sp. (laban), *Tectona grandis* (teak), and *Instia bijuga* (merbau). The wooden ship makers and users are usually reluctant to use new species of wood, even though the wood species have the same properties, maybe even better than the commonly used wood species. Traditional wooden ship usually
uses large-diameter solid wood raw materials to form the ship’s body and other components with limited design and technology. This phenomenon leads to inefficient use of raw materials, while the availability of wood raw materials decreases. The imbalance between demand and supply of wood needs to be anticipated because it could threaten the sustainability of the forest as well as the wooden ship industry.

The local ship industry which currently exist in several regions is small-medium scales traditional wooden ship industry that are operated dynamically as legacy from their predecessors. The industry requires the support of providing good quality raw timber that usually produced from natural forest. However, the need for wood can lead to excessive exploitation of natural forests which could threaten forest sustainability. Therefore, the utilization of wood as raw materials from plantation and community forests is highly recommended. Community forests or plantations have been proposed as potential sources of raw materials and timber can be used for various purposes to close the gap between demand and supply of timber [1]. The use of wood for shipping has been carried out for a long time in Indonesia, but the database for wooden ship for all regions in Indonesia are still incomplete. An inventory is needed to obtain data on the wood species that commonly used for shipping in various regions so that it can be used as comparison materials. It is also necessary to examine the alternative wood species that might be used for shipping in addition to the wood species that are commonly used. This study aims to invent the wood species that currently used for wooden ships in coastal areas of Riau Islands, the Northern and Southern Coast of Java. The identified wood species are used to determine alternative wood species based on wood properties approach.

2. Materials and methods

2.1. Inventory in the coastal areas

The inventory was conducted by collecting data and information related to wooden shipbuilding from the coastal areas of Riau Islands, the Northern and Southern Coast of Java. The targeted respondents for in-depth interview about current status of wooden ship industries were the district government officers, wooden ship industries and fishermen. Wood samples were collected from traditional wooden ship industries at the coastal areas of Riau Islands, the Northern and Southern Coast of Java. For Riau Island, the selected study areas were Tanjung Pinang and Batam island. Four location of shipbuilding industries in Tanjung Pinang were visited i.e. Kampung Bulang, Tanjung Unggat, Teluk Bakau and Sungai Jang. In Batam, two locations were visited i.e. Temoyong and Jaluh island. In Northern Coast of Java, the visited location was in Cirebon areas, while for Southern Coast of Java was in Sukabumi and Ciamis regency.

2.2. Identification of wood species

Wood identification was undertaken macroscopically in the studied areas using sharp cutter and loupe based on the guideline for identification in the field [2,3]. The unidentified wood samples were then observed microscopically at the laboratory (Figure 1). Microscopic slides of wood samples were prepared according to botanical microtechnique procedure [4] by preparing small wood samples of (1.5x1.5x1.5) cm to be softened in boiling water for about 1-2 hours, then submerged into 50:50 proportion of alcohol and glycerine for 2-3 days. The samples were sliced by a rotary microtome to obtain 15-25 µm thick covering cross, radial and tangential sections. The sliced samples were washed with distilled water, stained with safranin, dehydrated with a series of ethanol solutions (30%, 50%, 70%, 96% and absolute), cleared with xylene and toluene simultaneously. The cleared specimens were mounted on a glass object using entellan before observation under light microscope for anatomical features as listed by IAWA Committee [5]. The observed microscopic features were used to identify wood species using wood identification software [6] that also can be accessed online at www.xylarium.pustekolah.org. The samples were then matched with the collection of Xylarium Bogoriense as authentic reference.
Determination of alternative wood species

Determining alternative wood species was undertaken by using wood properties approach. The anatomical properties such as the type of fibre, vessels, rays, and parenchyma were considered to determine alternative wood species which has similar characteristics. The other wood properties such as wood density, strength quality and natural durability were also considered and collected from literature to support the proposed alternative wood species. Wood species which have similar wood properties with the identified samples were determined as alternative wood species for shipping industry.

3. Results and Discussion

3.1. Current status of wooden shipbuilding

The result showed that many wooden shipbuilding industries still exist in targeted locations and were usually managed by the small-medium enterprises. Generally, the wood species used were wood species that easily found and available around the industrial center. Wood materials from other areas sometimes required to obtain the targeted quality.

3.1.1. Riau Islands

Two districts of Riau Islands were visited i.e. Tanjung Pinang and Batam island. Wooden boats still become the most favourite type of boat for fishermen. However, the main problem faced in Riau Islands was the increasing demand for wood raw materials but the availability of raw materials were increasingly limited. The timber demand in Tanjung Pinang were approximately 1000 tons/month. Lingga island was the best source for providing high quality timber, but it was constrained by the licencing difficulties to extract timber from the island. In order to meet the needs of raw materials, the community also uses wood from their own land. In addition, wood raw materials are also ordered from Kuala Gaung, Indragiri Hilir Regency and another island especially Kalimantan by large company in order to get large diameter of log. The main priority is to obtain the material for “lunas” or keel component that require high quality of log with minimum diameter of 16 cm, straight form and minimum length of 7 meters.

The shipbuilders were used balau (Shorea sp.), ulin (Eusideroxylon sp.), laban (Vitex sp.), resak (Vatica sp.), and teak (Tectona grandis) for making keel component. High quality keel is mainly considered as the main structural part and backbone of a ship or boat. For the wall or deck board section used wood species that are easily accessible in the surrounding area such as meranti merah (Shorea sp.), laban (Vitex sp.), teak (Tectona grandis), gerontgang (Cratoxylon sp.), and nyirih (Xylocarpus sp.). For the “gading” section, the shipbuilders used branches of the tree species of laban (Vitex spp.), sop-sop (Sapotaceae) and bakau (Rhizophoraceae). They also used teak wood boards and meranti for fiber vessels. For “pasak” or thole pins component used pung wood (Dichrostachys sp),

![Figure 1. The unidentified samples from studied areas of shipbuilding industries](image-url)
ulin (Eusideroxylon sp.), tempinis (Sloetia sp.) and resak (Vatica sp.). They also aware to protect wood material from biodeterioration by applying traditional using lubricant oil and paint for coating.

### 3.1.1. Kampung Bulang, East Tanjung Pinang sub district

In Kampung Bulang, the boat used was a boat for fishing measuring 15x3 m with a capacity of <10 tons. The size of keel to make the boat was 10x8x12 m. The cost of making a boat is approximately IDR 40 million/unit. The type of wood used is meranti (Shorea sp.) for board and resak for keel part originating from Lingga Island, sop-sop and mangrove wood for gading, nyirih and bintangur (Calophyllum sp.) for decking board. The price of wood was approximately IDR 70,000/piece. For gading part, they used branch part of the trees. The method used to look for gading raw material is to use a jig plan to find a suitable part of the tree branch in the forest. If there are no suitable branches, then the side of the branches were used and put together using screws. To close the hole between the boards using putty powder following the use of gelam wood and gum resin.

### 3.1.2. Tanjung Unggat, Bukit Lestari sub district, Tanjung Pinang

Traditional shipbuilder in this location made a ship with 70 tons capacity with 60 feet length and 4 m width (Figure 2). They need 50 feet wood material to make keel. Wood species used are resak and balau (lunas), resak (ship body), sop-sop/teruntum (web frames), meranti (board), pung wood for thole pins. For filling the gap between board, they used gunny ropes and damar resins for gluing. At that time, they purchased resak wood for IDR 8 millions/ton. They need about 5 months with 4 crews to finish the ship making, so that they usually make 2 ships in a year.

![Figure 2. Wooden ship making in Tanjung Unggat, Tanjung Pinang](image)

### 3.1.3. Teluk Bakau, Gunung Kijang sub district, Tanjung Pinang

In Teluk Bakau, the problem of the occurrence of wood damage due to the attack of wood destroying organisms has observed (Figure 3). The organisms found mostly from the Teredinidae family, there are Martesia striata and Limnoria attacks on damaged boats.
Figure 3. The observation on damaged wooden ship in Teluk Bakau, Tanjung Pinang

3.1.1.4. Sungai Jang, Tanjung Pinang

Beside the traditional wooden ship, there were some company producing speed boat and cruise ship as well (Figure 4). One of companies located in Sungai Jang namely PT. Dasasari Galangan Kapal. This company producing speed boat based on order or for the needs of the company itself. They produced speed boat with size 10 m long, 4 m wide and 3 m high for 15 passengers capacity. They used wood species such as geronggang and resak for making keel, balau for double hull (lambung). The wood material used was purchased from Lingga island. The price for balau and resak was 12 million Rupiah/ton, while geronggang was 9-10 million Rupiah/ton. The company also used plywood for making web frames (gading) and board component. Plywood material was produced by plywood company in Gresik, East Java, but they could not order in small scale (< 1000 pieces), so that they prefer to import the plywood from Singapore for small order.

Figure 4. Produced Speed boat in Sungai Jang, Tanjung Pinang

3.1.1.5. Temoyong and Jaluh Island, Bulang sub district, Batam Regency

The shipbuilders in this small island made boat for inter-island transportation and fishing that usually called “boat pancung” with the length of 28 feet and the width of 5 feet. They also made “sampan” or a small boat typically with an oar or oars at the stern with the length of approximately 20 feet. The production capacity was 13 boats/year to make boat 18 feet long. Various wood species were used such as seraya (Shorea sp.) for making board, selumar (Mussaendopsis beccariana) for keel, perepat (Sonneratia alba) and nangka for web frames, teraling (Tarrietia symplicifolia) for “soak” (front board) and back part, and tempinis (Sloetia sp.-Moraceae) for thole pins. The wood material was obtained from Bulang Forest. In addition, they still prefer to use solid wood rather than plywood because of better resistance to weather. Figure 5 shows the visited location in Temoyong island.
3.1.2. Northern Coast of Java

Most people in Cirebon Regency work as fishermen, so the need for sea transportation was very high. The boat-making industry centers in Cirebon Regency were located in Gebang Sub-District (Gebang Kulon, Gebang Hilir, Gebang Udik, and Gebang Mekar Village), Mundu Sub-District (Citemus Village), Bondet and Gunung Jati Sub-District. The center of the boat-making industry was mostly found in Gebang Sub-District. In each village there were many boat maker groups, for example in Gebang Kulon village there were approximately 11 centers. The raw materials for making boats were mainly teak (*Tectona grandis*) and merbau (*Intsia* sp.) wood. Teak wood used comes from Pasalama, Karang Sembung, Sedong, Susukan Lebak, and Karang Wareng Sub-District. While merbau wood was obtained from Papua which is specifically supplied by PT. Berkat Jaya in Cirebon.

![Figure 5. Studied area in Temoyong island, Batam regency](image)

3.1.3. Southern Coast of Java

3.1.3.1. Pelabuhan Ratu, Sukabumi Regency

The location for making and repairing boats in Pelabuhan Ratu was centralized at Pelabuhan Perikanan Nusantara. At that location, a shrimp nets boat was being made or commonly called a double mini boat. The boat made was a boat with a full length of 8 m, a length of 9.5 m, a width of 2.20 m with a payload capacity of <10 GT (Gross Ton). The largest size of the boat made was 18 m in length with a tonnage of more than 30 GT. The type of boat used to make seaweed plants is called

![Figure 6. Wooden shipbuilding industry in Cirebon regency](image)
rumpon or FADs (Feed Aggregating Device) boat with a size of 12 m keel length, a top length of 15 m, and a width of 3 m. The wood species used are bayur (Pterospermum sp.) and benger / bungur (Lagerstroemia sp.) for boat boards, laban (Vitex sp.) for web frames and linggi (stem), and taritih (Parinari corymbosa) for keel. The wood used was purchased from farmers. The price of laban wood was IDR 25,000/m$^3$, taritih wood was IDR 4-5 million/m$^3$ (sold in the form of a 15 m long board), bayur wood IDR 3.2 million/m$^3$. The price of the boat was IDR 25 million without the engine. The lifetime of the boat depends on maintenance, for good maintenance, the docking activities would be carried out approximately after 5 years.

3.1.3.2. Pangandaran, Ciamis Regency
Currently the boat used mostly made of fiberglass (Figure 7), while the use of wooden boats have not been produced for a long time and only came from Cilacap Regency. After the tsunami disaster, the use of wooden boats switched to fiberglass from the government’s aid. According to fisherman, fiber boats are easier and faster to make, and easy to maintain because if the boat is leaking it is only necessary to fill in the leaked part. Wood species used in the past were caruy / bayur wood (Pterospermum sp), albasia putis (Paraserianthes sp.), abasia merah (Albizia sp). Red albasia was commonly used to make jukung boats. The size of the fiberglass boat made 9.30 - 9.60 m in length with a width of 1.10 - 1.50 m for capacity less than 1 ton. In the manufacture of fiber boats, wood raw material were still used for web frames and upper boards. The used wood species were red jeunjing, white jeunjing, waru laut, and waru gunung. Red jeunjing is known to be stronger than white jeunjing, while waru laut (Thespesia sp.) was known to be better than waru gunung (Hibiscus sp.) that easily broken.

![Figure 7. The product of fiberglass boat in Pangandaran, Ciamis regency](image)

3.2. Microscopic wood identification
Various wood species were used for different part of ship components. Each component of wooden ship has specific criteria for wood species selection depending on the function of the component. For example, high density wood was used for keel component as the main structural function of wooden ship. This section describes the anatomical features of wood samples from the studied areas that could not be identified in the field. Table 1 presents the information of the observed wood samples.

Table 1 represents that the same local name in different location might has different wood species. For example, pung wood used in Northern coast of Java was actually different with pung wood from Riau Islands. The scientific name of selected wood samples were used as guidance to determine alternative wood species.
Table 1. Wood identification result for unidentified sample from different study areas

| Sample code | Sample name | Utilization purpose | Location | Identified wood species |
|-------------|-------------|---------------------|----------|------------------------|
| 2           | Pung        | Thole pins          | Cirebon, Northern Coast of Java | *Dichrostachys cinerea* |
| 4           | Jati        | Keel                | Cirebon, Northern Coast of Java | *Tectona grandis* |
| 6           | Pung        | Thole pins          | Tanjung Unggat, Tanjung Pinang | *Ormosia subseraceae* |
| 9           | Teruntum/sop-sop | Wall, web frames | Tanjung Unggat, Tanjung Pinang | *Lumnitzera littorea* |
| 15          | Sop-sop     | Web frames          | Kampung Bulang, Tanjung Pinang | *Lumnitzera littorea* |
| 18          | Resak       | Keel, thole pins    | Sungai Jang, Tanjung Pinang   | *Shorea sp* (Balau) |
| 19          | Geronggang  | Keel                | Sungai Jang, Tanjung Pinang   | *Shorea sp* |
| 20          | Medang      | Boards              | Temoyong Island, Batam        | *Alseodaphne sp.* |

Figure 8. *Dichrostachys cinerea*: a. macroscopic (scale bar: 1 mm), b. transverse section (scale bar: 200 μm) c. Radial section (scale bar: 100 μm), d. Tangential section (scale bar: 100 μm)

3.2.1. Pung wood from Northern Coast of Java
Pung wood sample from Northern Coast of Java (sample number 2) has anatomical characteristics i.e. growth ring boundaries indistinct (2), simple perforation plate (13), 5 - 20 vessels per square millimetre (47), intervessel pit alternate (22), gums and other deposits in heartwood vessels (58), fibres with simple to minutely bordered pits (61), non-septate fibres present (66), fibres very thick-
walled (70), axial parenchyma vasicentric (79), axial parenchyma aliform (80), axial parenchyma confluent (83), 3-4 cells per parenchyma strand (92), ray width 1 to 3 cells (97), all ray cells procumbent (104), 4-12 rays/mm² (115), prismatic crystal present (136), prismatic crystals in chambered axial parenchyma cells (142). Based on identified anatomical features, the sample of pung wood from Northern Coast of Java was identified as *Dichrostachys cinerea* that belongs to Leguminosae family (Figure 8). The number in parentheses is the IAWA identification [5].

3.2.2. Jati wood sample from Northern Coast of Java
Jati wood sample from Northern Coast of Java (sample number 4) has anatomical characteristics i.e. growth ring boundaries distinct (1), wood ring-porous (3), simple perforation plate (13), intervessel pit alternate (22), 5 - 20 vessels per square millimetre (47), tyloses (56), gums and other deposits in heartwood vessels (58), fibres with simple to minutely bordered pits (61), septate fibres present (65), fibres thin- to thick-walled (69), 3-4 cells per parenchyma strand (92), ray width 1 to 3 cells (97), rays commonly 4-10 seriate (98), larger rays commonly ≥10 seriate (99), all ray cells procumbent (104), body ray cells procumbent with one row of upright cells (106), Rays ≤4/mm (114).

![Figure 9. Tectona grandis: a. macroscopic (scale bar: 1 mm), b. transverse section (scale bar: 200 μm), c. Radial section (scale bar: 200 μm), d. Tangential section (scale bar: 200 μm)](image-url)
Based on identified anatomical features, the sample of jati wood was identified as *Tectona grandis* (Lamiaceae) (Figure 9). The anatomical characteristics of this sample was similar to fast growing teak wood which has larger rays than conventional teak.

3.2.3. Pung wood from Tanjung Pinang
Pung wood sample from Tanjung Pinang (sample number 6) has anatomical characteristics i.e. growth ring boundaries indistinct (2), wood diffuse-porous (5), simple perforation plate (13), vessel-ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell (30), fibres with simple to minutely bordered pits (61), fibres thin to thick walled (69), axial parenchyma vasicentric (79), axial parenchyma aliform (80), axial parenchyma winged aliform (82), axial parenchyma confluent (83), ray width 1 to 3 cells (97), all ray cells procumbent (104), 4-12 rays/mm² (115), prismatic crystal present (136), prismatic crystals in chambered axial parenchyma cells (142). Pung wood from Tanjung Pinang was identified as *Ormosia subseraceae* (Papilionaceae) (Figure 10) that different with pung wood from Northern Coast of Java which identified as *Dichrostachys cinerea* (Leguminosae).

![Figure 10. Ormosia subseraceae: a. macroscopic (scale bar: 1 mm), b. transverse section (scale bar: 200 µm), c. Radial section (scale bar: 100 µm), d. Tangential section (scale bar: 50 µm)](image-url)
3.2.4. Teruntum or sopsop wood from Tanjung Pinang

Teruntum wood sample from Tanjung Pinang (sample no 9 and 15) has anatomical characteristics i.e. growth ring boundaries indistinct (2), wood diffuse-porous (5), vessels in radial multiples of 4 or more common (10), simple perforation plate (13), intervessel pits alternate (22), vested pits (29), 20 - 40 vessels per square millimetre (48), fibres with simple to minutely bordered pits (61), non-septate fibres present (66), Fibres thin- to thick-walled (69), Axial parenchyma scanty paratracheal (78), Rays exclusively uniseriate (96), All ray cells procumbent (104), 4-12 rays / mm (115). Teruntum wood has identified as *Lumnitzera littorea* (Combretaceae) (Figure 11).

![Figure 11. Lumnitzera littorea: a. macroscopic (scale bar: 1 mm), b. transverse section (scale bar: 200 μm), c. Radial section (scale bar: 100 μm), d. Tangential section (scale bar: 100 μm)](image)

3.2.5. Resak wood sample from Tanjung Pinang

The shipbuilder in Tanjung Pinang said that wood sample number 18 as resak. However, the identification result was *Shorea* sp. (Dipterocarpaceae) that belongs to balau group (Figure 12). The color and appearance of the sample with resak wood is similar, so that people assume as resak. The
anatomical characteristics are growth ring boundaries indistinct (2), wood diffuse-porous (5), simple perforation plate (13), vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular (31), ≤ 5 vessels/mm² (46), tyloses common (56), fibres with simple to minutely bordered pits (61), Fibres very thick-walled (70), Axial parenchyma aliform (80), axial parenchyma confluent (83), ray width 1 to 3 cells (97), 4-12 rays/mm (115), Axial canals in long tangential lines (127), prismatic crystal present (136), prismatic crystals in chambered axial parenchyma cells (142).

**Figure 12.** *Shorea* sp. (Balau): a. macroscopic (scale bar: 1 mm), b. transverse section (scale bar: 200 μm), c. Radial section (scale bar: 100 μm), d. Tangential section (scale bar: 50 μm)

3.2.6. Geronggang wood sample from Tanjung Pinang

Wood sample number 19 from Tanjung Pinang has anatomical characteristics i.e. growth ring boundaries indistinct (2), wood diffuse-porous (5), intervessel pits alternate (22), vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular (31), ≤ 5 vessels per square millimetre (46), tyloses common (56), fibres thin- to thick-walled (69), axial parenchyma in narrow bands or lines up to three cells wide (86), ray width 1 to 3 cells (97), 4-12 rays/mm (115), axial canals in long tangential lines (127). The sample was identified as *Shorea* sp. (light-red meranti) belong to
Dipterocarpaceae family (Figure 13). Local people in studied area showing the sample as geronggang wood, however the identification result show as light-red meranti.

**Figure 13.** *Shorea* sp. (light-red meranti): a. macroscopic (scale bar: 1 mm), b. transverse section (scale bar: 200 µm), c. Radial section (scale bar: 100 µm), d. Tangential section (scale bar: 200 µm)

### 3.2.7. Medang wood sample from Batam

Medang wood (sample number 20) from Batam has anatomical characteristics i.e. growth ring boundaries indistinct (2), wood diffuse-porous (5), Solitary vessel outline angular (12), simple perforation plates (13), intervessel pits alternate (22), vessel-ray pits with much reduced borders to apparently simple: pits rounded or angular (31), vessel-ray pits with much reduced borders to apparently simple: pits horizontal (scalariform, gash-like) to vertical (palisade) (32), vessel-ray pits of two distinct sizes or types in the same ray cell (33), 5 - 20 vessels per square millimetre (47), fibres with simple to minutely bordered pits (61), septate fibres present (65), fibres thin- to thick-walled (69), axial parenchyma vasicentric (79), ray width 1 to 3 cells (97), body ray cells procumbent with one row of upright and / or square marginal cells (106), 4-12 rays/mm (115), oil and / or mucilage cells associated with axial parenchyma (125), oil and / or mucilage cells present among fibres (126). The wood sample has identified as *Alseodaphne* sp. (Lauraceae) (Figure 14).
3.3. Alternative wood species for wooden ship

Determination of alternative wood species was based on the wood properties of identified wood samples i.e. Dicrostachys cinerea, Tectona grandis, Ormosia subseraceae, Lumnitzera littorea, Shorea sp. (balau), Shorea sp. (light-red meranti), and Alseodaphne sp. The supporting data for vernacular name wood density, and trade group category were collected from the Xylarium database and PROSEA 5 vol. 1-3 [7-9]. The alternative wood species and related properties are presented in Table 2. Most alternative wood species belongs to lesser-known wood species include some identified samples. It means that people in the coastal areas have already utilize lesser-known wood species as a result of limited stock of commercial timbers. It can be seen from Table 2 that the similar properties on wood anatomy also related to density and their trade group categories. One of important anatomical properties is the cell wall thickness that has strong correlation with the mechanical properties [10]. Therefore, the cell wall thickness has considered to be the main criteria in determining the alternative wood species. In addition, study showed that density also correlated positively with natural durability [11].
| Identified wood species | Alternative wood species | Family | Vernacular name | Anatomical properties* | Density (kg/m\(^3\))** | Trade group |
|-------------------------|--------------------------|--------|----------------|------------------------|-------------------------|-------------|
| *Dickrostachys cinerea* | Leguminosae | Epung (Javanese), pereng (Madurese), pung (Sundanese) | 2, 13, 22, 47, 58, 61, 66, 70, 79, 80, 83, 92, 97, 104, 115, 136, 142 | 600-1190 | Medium-weight to heavy hardwood |
| *Acmena* sp. | Myrtaceae | Kelat | 2, 13, 22, 47, 58, 61, 70, 79, 80, 83, 97, 136, 115 | 720-940 | Medium-weight to heavy hardwood |
| *Avicennia* sp. | Avicennaceae | Api-api, white mangrove | 2, 13, 22, 47, 58, 61, 70, 79, 80, 83, 97, 136, 115 | 560-800 | Medium-weight hardwood |
| *Ziziphus* type B | Rhamnaceae | Bidara, widara | 2, 13, 22, 47, 58, 61, 70, 79, 80, 83, 97, 136, 115 | 535-1180 | Medium-weight to heavy hardwood |
| *Aglaia* sp. | Meliaceae | Parak, langsat (Kalimantan) | 2, 13, 22, 47, 58, 61, 70, 79, 80, 83, 136, 115 | 450-1200 | Medium-weight to heavy hardwood |
| *Tectona grandis* | Lamiaceae | Jati | 1, 3, 13, 22, 47, 58, 62, 65, 69, 92, 97, 98, 99, 104, 106, 114 | 610-750 at 12% Moisture content | Medium-weight hardwood |
| *Ehretia* sp. | Borraginaceae | kendal | 1, 3, 13, 22, 69, 98, 115 | 490-670 (715) | Medium-weight hardwood |
| *Morus* sp. | Moraceae | murbei, mulberry | 1, 3, 13, 22, 69, 98, 115 | 670-850 | Medium-weight hardwood |
| *Peronema* sp. | Verbenaceae | Sungkai, jati sabrang, jati londo (Java), kurus (Kalimantan) | 1, 3, 13, 22, 98, 115 | 520-730 | Light to medium-weight and moderately hardwood |
| *Azadirachta* sp. | Meliaceae | Kayu bawang, surian bawang, bawang kunyit (Kalimantan), nibwak (Papua) | 1, 3, 13, 22, 98, 115 | 550-780 | Sentang (A. excelsa): lightweight to medium-weight |
| *Toona* sp. | Meliaceae | Surian, suren | 1, 3, 13, 22, 69, 98, 115 | 270-530 | Neem (A. indica): moderately heavy hardwood |
| *Cedrela* sp. | Meliaceae | hp | 1, 3, 13, 22, 98, 115 | 410-525 | Lightweight hardwood |
| *Lagerstroemia* sp. | Lythraceae | bungur | 1, 3, 13, 22, 69, 97, 115 | 505-810 | Medium-weight hardwood |
| *Cathormion* sp. | Lythraceae | Lambaran (Sundanese), lom (Javanese), kiutasi (Timor) | 2, 5, 13, 30, 47, 61, 69, 80, 83, 97, 104, 115, 136, 142 | 720-840 | Medium-weight hardwood |
| *Ormosia subseraceae* | Papilionaceae | Kupang | 2, 5, 13, 30, 47, 61, 69, 79, 80, 82, 83, 97, 104, 115, 136, 142 | 480-830 | Medium-weight hardwood |
| *Crudia* sp. | Caesalpiniaceae | baby kurus, merbau kapur | 2, 5, 13, 30, 47, 61, 69, 80, 83, 97, 104, 115, 136, 142 | 740-1125 | Medium-weight but usually heavy hardwood |
| *Ganophyllum* sp. | Sapindaceae | Mangir, ki angir (Sundanese), tapus (Sumatera) | 2, 5, 13, 30, 47, 61, 69, 80, 83, 97, 104, 115, 136, 142 | 650-1000 | Medium-weight to heavy hardwood |
| *Kingiodendron* sp. | Caesalpiniaceae | kingiodendron - philippina-PNG | 2, 5, 13, 30, 47, 61, 69, 80, 83, 97, 104, 115, 136, 142 | 450-760 | Medium-weight to heavy hardwood |
| Species                      | Family               | CommonNames                                      | Volumes | PriceRange | WeightClass                      |
|-----------------------------|----------------------|--------------------------------------------------|---------|------------|----------------------------------|
| Sympetalandra sp. 3)        | Leguminosae-Caesalpiniaeae | Merbau lalat                                     | 2, 5, 13, 30, 47, 61, 69, 80, 83, 97, 104, 115, 136, 142 | 640-910 | medium-weight hardwood, occasionally heavy |
| *Tristiropsis* sp. 3)       | Sapindaceae          | Tristiropsis acutangula: hende, lere (Flores), kugwo (Istja). T. ferruginea: laras (East Kalimantan) | 2, 5, 13, 30, 47, 61, 69, 80, 83, 97, 104, 115, 136, 142 | 580-795 | Medium-weight hardwood            |
| *Xerospermum* sp. 3)        | Sapindaceae          | X. noronhianum: burundul, corongol monyet (Sundanese) | 2, 5, 13, 30, 47, 61, 69, 80, 83, 97, 104, 115, 136, 142 | 580-795 | Medium-weight hardwood            |
| *Lumnitzera littorea*       | Combretaceae         | Termuntum, Taruntung (Java, Sumatera), sesop (Sumatera), Soposop (Peninsular, Sarawak) | 2, 5, 10, 13, 22, 29, 48, 61, 66, 69, 78, 96, 104, 115 | 750-970 | Medium-weight to heavy hardwood   |
| *Guettarda* sp. 3)          | Rubiaceae            | jati pasir, titi laut (Maluku), kenang-kenang (Madura) | 2, 5, 10, 13, 22, 48, 29, 69, 115 | 640-840 | Medium-weight hardwood            |
| *Anthocephalus* sp. 1)      | Rubiaceae            | Jabon (Java), laran (Kalimantan), emajang (Sumatera) | 2, 5, 10, 13, 22, 29, 66, 69, 115 | 290-465 | Lightweight to medium-heavy hardwood |
| *Shorea* sp. (dark-red meranti) i.e. S. curtissi, S. micrantha, S. ovata, S. pauciflora, S. platycados 1) | Dipterocarpaceae | Meranti merah tua: biji, biji (Borneo), puchong (Sumatra) | 2, 5, 10, 13, 22, 29, 66, 69, 115 | 600-860 | Lightweight to medium-heavy hardwood |
| *Acacia* sp. 2)             | Leguminosae          | Akasia                                           | 2, 5, 10, 13, 22, 29, 66, 69, 115 | 560-1000 | Medium-weight hardwood            |
| *Copafera palustris* 2)     | Leguminosae          | Emputir, sepetir                                 | 5, 10, 13, 22, 29, 69, 115 | 640-1050 | Medium-weight hardwood            |
| *Syzygium* sp. 2)           | Myrtaceae            | Kelat, ki tembaga, jambu laut                     | 2, 5, 10, 13, 22, 29, 69, 115 | (450-520-925(-1100) | Medium-weight to heavy hardwood |
| *Shorea* sp. (Balau)         | Dipterocarpaceae     | Balau                                             | 2, 5, 13, 31, 46, 56, 61, 70, 76, 77, 80, 83, 97, 115, 127, 136, 142 | 600-850-1160 | Heavy hardwood                      |
| *Irvingia* sp. 3)           | Simaroubaceae        | Bongin, kayu batu (Borneo), pauh kijang (Sumatra) | 2, 5, 13, 31, 46, 56, 61, 70, 80, 83, 97, 115, 136 | 930-1250 | Heavy hardwood                      |
| *Carallia* sp. 3)           | Rhizophoraceae       | Ringgit dareh                                    | 2, 5, 13, 31, 46, 56, 70, 80, 83, 115, 136 | 640-1050 | Medium-weight to heavy hardwood   |
| *Bauhinia* sp. 3)           | Caesalpiniaeae       | Benculuk, kendayakan (Java), kripi (Sumatra)     | 2, 5, 13, 31, 46, 61, 70, 80, 83, 97, 115, 136 | 665-820 | Medium-weight hardwood            |
| *Barringtonia* sp. 3)       | Lecythidaceae        | Putat, butun, keben (Javanese), songgom (Sundanese), Malaysia: tampalang | 2, 5, 13, 31, 46, 61, 70, 80, 83, 115, 136 | 480-815 | Medium-weight hardwood            |
| *Shorea* sp. (light red meranti) | Dipterocarpaceae     | Meranti merah muda, seraya merah, meranti bunga | 2, 5, 22, 31, 46, 56, 69, 86, 97, 115, 127 | 300-600 | Lightweight hardwood              |
4. Conclusion

Various wood species were used for different parts of ship components which has specific criteria depending on the function of the component. For structural component like keel, high quality wood material (high density, large diameter and straight form) is required. The botanical identity of wood species is important for wood material selection rather than local name. Similar macroscopic features has caused misinterpretation in determining wood material that might give effect on the quality of the product. The alternative wood species for wooden ship materials have been proposed based on the wood properties of identified wood species that currently used in the studied areas. Most alternative wood species are belong to lesser-known wood species that can be potentially utilized as wooden ship materials. It is hoped that the recommendation of alternative wood species could give more options for material selections and solve the problem of decreasing supply of current commercial wood.

References

[1] Obidzinski K and Dermawan 2010A Smallholder timber plantation development in Indonesia: what is preventing progress? Int. For. Rev. 12(4) 339–48
[2] Mandang YI and Pandit IKN 1997 Pedoman Identifikasi Jenis Kayu di Lapangan (Bogor: Yayasan PROSEA)
[3] Damayanti R dan Mandang YI 2007 Pedoman Identifikasi Jenis kayu Kurang Dikenal (Bogor: Pusat Penelitian dan Pengembangan Hasil Hutan)
[4] Sass J 1961 Botanical Microtechnique. Third Edition (Iowa: The Iowa State University Press)
[5] Wheeler EA, Baas P and Gasson PE 1989 IAWA list of microscopic features for hardwood identification
[6] Mandang Y 2004 Kunci Identifikasi Kayu Asia Tenggara
[7] Soerianegara I and Lemmens R 1993 Plant resources of South-East Asia vol 5(1) Timber Trees: major commercial timbers pp 384–91
[8] Lemmens RH, Soerianegara I and Wong WC 1995 Plant resources of South-East Asia vol 5(2) Timber trees: minor commercial timbers
[9] Sosef MSM, Hong LT and Prawirohatmodjo S 1998 Plant Resources of South-East Asia: Timber Trees: Lesser-known timbers, vol 5(3) (Backhuys Leiden)
[10] Jeong GY 2013 Relationship between anatomical and mechanical properties of loblolly pine (Pinus taeda) For. Prod. J. 63(1–2) 47–53
[11] Dadzie PK and Amoah M 2015 Density, some anatomical properties and natural durability of stem and branch wood of two tropical hardwood species for ground applications Eur. J. Wood Prod. 7(36) 759–773

Acknowledgement
This research was financially supported by the Ministry of Research, Technology and Higher Education. Invaluable support has also given by Forest Products Research and Development Center, The Ministry of Environment and Forestry, Indonesia for laboratory and administrative facilities. We also thank to all respondents i.e. local governments, wooden ship industries and fishermen from studied areas for their kind cooperation. This paper also tributes to Dra. Sri Rulliaty, M.Sc. and Ir. Edi Sarwono (RIP) for the great team work during field study.