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THE EFFECT OF SHIPBUILDING MATERIAL TYPE ON BIOFOULING GROWTH AT BOOM MARINA, BANYUWANGI, EAST JAVA, INDONESIA

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ABSTRACT

The presence of biofouling has an impact on the ship's performance, which is reduced to require more fuel, in the end, it contributes significantly to cost increases. Biofilms provide a suitable substrate for the growth of microorganisms. Ship hull as a substrate for biofilms has many kinds of material. Steel, wood, laminated bamboo, and fiber are often used for ship hulls. Different material makes different characteristics of substrate for biofilms. The aim of this research is to determine the growth rate of biofouling in each shipbuilding material and to find out which vessel material is suitable for use in the Bali Strait. The experiment was located in Boom Marina, Banyuwangi. The materials used in this research are wood, laminated bamboo, and fiber. The daily growth rate (DGR) is calculated every week of observation. Wood had the most biofouling with a DGR of 2,646 g/day. Laminated bamboo had the least biofouling in this research after 2 months of immersion with a DGR of 0,086 g/day.

***Keywords**: Biofouling, shipbuilding material, daily growth rate.*

INTRODUCTION

Biofouling in the marine environment is the accumulation of microorganisms and macro organisms which are stick to the surface of the object (Pratama *et al.,* 2014). In the world of shipping, biofouling is a serious problem because it often occurs in the ship hull even in the submerged parts of the propeller and pipes water. The existence of this biofouling impacts vessel performance and leads to increased fuel consumption, ultimately contributing significantly to higher costs (Chan & Wong, 2010; Farkas *et al.,* 2020). The biofouling state and its effect need to monitor and evaluate, especially on the ship's hull and propeller. Marine biofouling threatens the ecological balance and causes a reduction in ship's hydrodynamic performance by the International Maritime Organization (IMO) research (Uzun *et al.,* 2019). According to the research, biofouling has effects on propeller performance (Valchev *et al.,* 2022). Biofouling grows naturally at different growth rates. The growth rate of biofouling on the ship is influenced by several factors, such as operating area, berth, sailing time ratio, ship hull painting method, speed service, as well as the frequency of berthing (Railkin, 2003; Valchev *et al.,* 2022). Other factors affecting growth biofouling are light intensity, salinity, tides, temperature, sedimentation, sea depths, currents, and water waves (Panjaitan, 2011). Regardless of the factors in this case, the growth of biofouling takes place in a fast time which begins with the appearance of a layer of mucus by the attachment of bacteria. The next factor is shipbuilding material, material specific makes an effect on fouling community composition (Chase, 2015). Surface properties such as the contact angle by the wettability of the surface (θc), micro-texture (m_t), surface roughness (R_t), and surface potential (σ) influence the attachment of biofouling (Uzun *et al.,* 2019). Choosing a material for an application in the ocean made a difference in total fouling coverage (Ryley *et al.,* 2021).

Bali Strait is an area that is affected by the phenomenon of upwelling (Radiarta & Sidik, 2021). The upwelling area is an area that is rich of nutrients. It can be a food supply for all marine biota, including biofouling. Bacteria will grow faster when more nutrients are available because nutrients are needed for respiration and bacteria survival (Abushaban *et al.,* 2022). The Bali Strait is a strait that connects Java and Bali so the shipping route there are very busy. Every ship has a different berthing time, affecting the biofouling attachment's thickness and the upwelling conditions in the Bali strait can accelerate biofouling growth potential. Boom Marina Banyuwangi is the port of yachts and is always crowded with traditional ships as a tourist vehicle with a prolonged time at berth. Fouling could develop quickly when some ships have prolonged time at berth (Due & Mepc, 2022). The selection of the appropriate material is thought to be able to minimize the occurrence of biofouling on the ship hull. Foulers from marine biota have complex characteristics. Many experiments were done to find out biofouling growth rate in many kinds of material but the results are diverse. Each water has different characteristics from others, this is the factor in the biofouling growth rate which varies in each material and water. All materials with different substrate characteristics had not significant differences in either species composition, biofouling growth rate, and total cover (S. Navarrete & Rojas, 2020). Biofouling occurs in most materials from plastics to ceramics but specific substrates can make as antifouling. Platinum-cured liquid silicone rubber (PC-SLR) can be used to minimize algal attachment in coral aquaculture because this material can reduce molecular attractions and provide a smooth surface that makes it more difficult for attachment (Hassinger, 2022). Another modification such as highly hydrophobic wood can make a good dimensional stability and anti-fouling property (Lin *et al.,* 2018). Different organisms have different characteristics. Sessile fouling organisms such as bivalves are frequently relocated through submerged man-made and natural substrates but non-native organisms lived through boat hulls, oil platforms, and aquaculture gear (Chase, 2015). This study aims to determine the growth rate of biofouling in each material shipbuilding and to find out which vessel material is suitable for use in the Bali Strait.

MATERIALS AND METHODS

Sampling and Data Collection

The research was conducted at the Boom beach, Banyuwangi with two locations for specimen immersion, inside the dock as new wharf with coordinate 8°12’35.6”S 114°22’54.8”E and the mouth of the dock as old wharf with coordinate 8°12’02.8”S, 114°22’55.5”E (**Figure 1**). There are 4 types of materials are analyzed, i.e., fiberglass, laminated bamboo, wood, and steel ASTM 36 are used in the shipping industry. All materials were made into 6 specimens with a size of 10 cm x 10 cm each. Specimens are suspended from the buoy using a wire then the buoy is tied to the pier. There are three specimens for each material to conduct Repeated Measures Designs (RMD). RMD is repeatedly observed under the treatment and has many advantages, such as maximum error control and we can get data more reliable than in a cross-sectional study. All specimens are soaked for 30 days and lifted every 7 days to find out biofouling growth. Bacterial biofilm formation is appeared within a week by spores of macroalgae, fungi, and protozoa. Within several weeks by larvae of invertebrates. Sometimes motile spores of seaweeds can settle within minutes and larvae of invertebrates can settle within a few hours of immersion (Callow & Callow, 2011). The next step is data collection. The primary data are collected from mass of material weighed periodically, and documentation of fouling growth.

Data analysis

Weighing is one day after immersion to get wet weight as initial weight, weekly sampling is used up to 1 month to determine the growth rate of biofouling. the specimens are lifted and then weighted with a digital balance. The data from weighing sessions are calculated with Daily Growth Rate (DGR) formula.

$$DGR\ (\%day^{-1}) = (\ln (W_t/W_0)/t)*100 \quad \ldots\ldots\ldots\ (1)$$

Where W_t is the weight at a given date, W_0 is the weight at the beginning of the experiment, and t is the number of days between W_0 and W_t (Meichssner *et al.,* 2020).

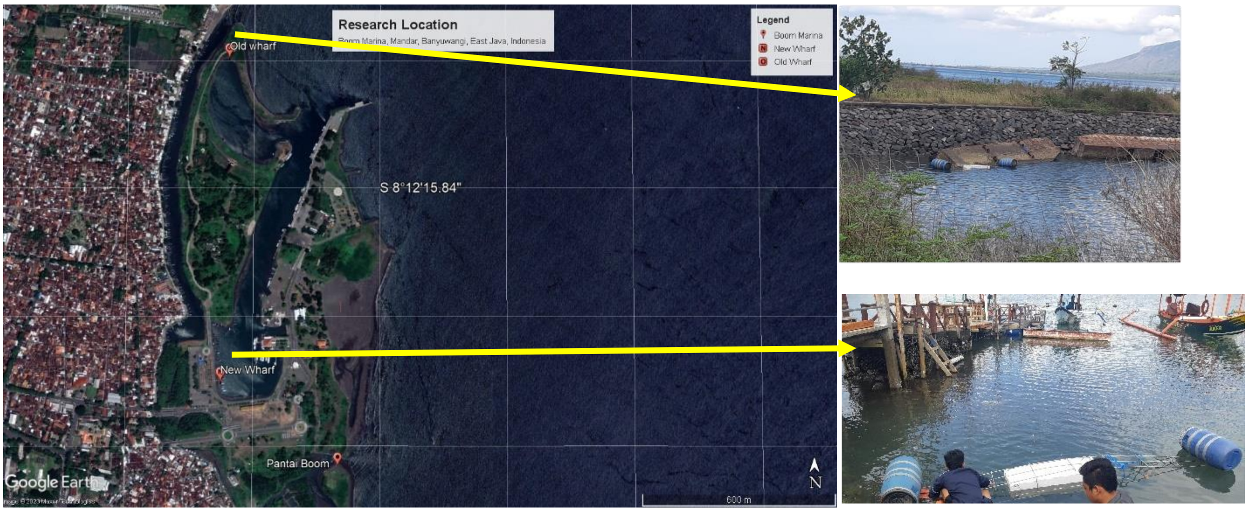


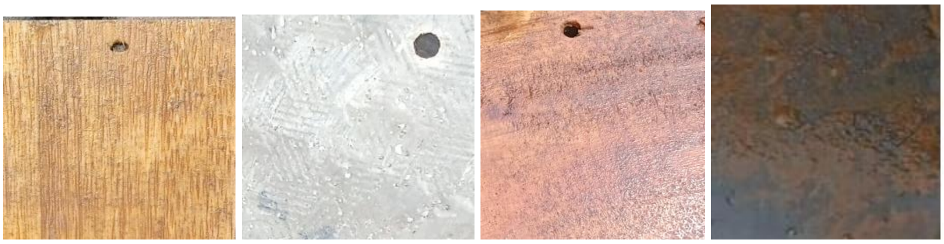
Figure 1. Experiment location in two sites (Google Maps, 2023)

RESULTS AND DISCUSSION

The condition of the materials after 1-month period are fluctuated. The materials in the first week, one day after immersion in new wharf are presented in **Figure 2** and one day after immersion in old wharf are presented in **Figure 3**.

(a) (b) (c) (d)

Figure 2. (a) Laminated Bamboo, (b) Fiberglass, (c) Wood, (d) Steel ASTM-36 one day after immersion in new wharf (with 2x zoom (5x5 cm))



(a) (b) (c) (d)

Figure 3. (a) Laminated Bamboo, (b) Fiberglass, (c) Wood, (d) Steel ASTM-36 one day after immersion in old wharf (with 2x zoom (5x5 cm))

All materials had biofilm after one week of immersion and became thicken after eight weeks immersion. Macrofouling began to appear in several materials on the new wharf and old wharf (**Figure 4** and **Figure 5**).

(a) (b) (c) (d)

Figure 4. (a) Laminated Bamboo, (b) Fiberglass, (c) Wood, (d) Steel ASTM-36 eight weeks after immersion in new wharf (with 2x zoom (5x5 cm))

(a) (b) (c) (d)

Figure 5. (a) Laminated Bamboo, (b) Fiberglass, (c) Wood, (d) Steel ASTM-36 eight weeks after immersion in old wharf (with 2x zoom (5x5 cm))

Based on the result, the specimens already had biofouling at one week after immersion. Even though biofouling has complex and slow process where microbial growth can take a couple of weeks or months, initial step or adsorption stage can occur in about two hours only (Agostini & Ozorio, 2022; Maddah & Chogle, 2017). Four stages of biofouling can occur within weeks, conditioning can occur in one minute to one hour, attachment of microbial can occur in one hour to 24 hours, colonization can occur in 24 hours to 1 week, and microbial growth as biofilm can occur in 2 weeks to 1 month (Maddah & Chogle, 2017; Matin *et al.,* 2011) After two months immersion, there are invertebrates on steel surfaces and macroalgae on wood, laminated bamboo, and fiberglass surfaces. In a month, biofouling reach the fourth stage that has small macro foulers such as *Ulva* sp. and *Bugula* sp. and large macro foulers such as *Balanus* sp., *Mytilus* sp., and *Spirorbis* sp. (Donnelly *et al.,* 2022). **Figure 4** and **Figure 5** show that steel has more variants of macrofouling than others. In the first sampling, steel has few or no species but after one year the coverage of macrofouling had increased on steel (Andersson *et al.,* 2009). All materials have full of coverage with hydrozoans. Hydrozoans with the species is *Obelia geniculate* can coverage 81,3% and Barnacle 3,3 % coverage (S. A. Navarrete *et al.,* 2020).

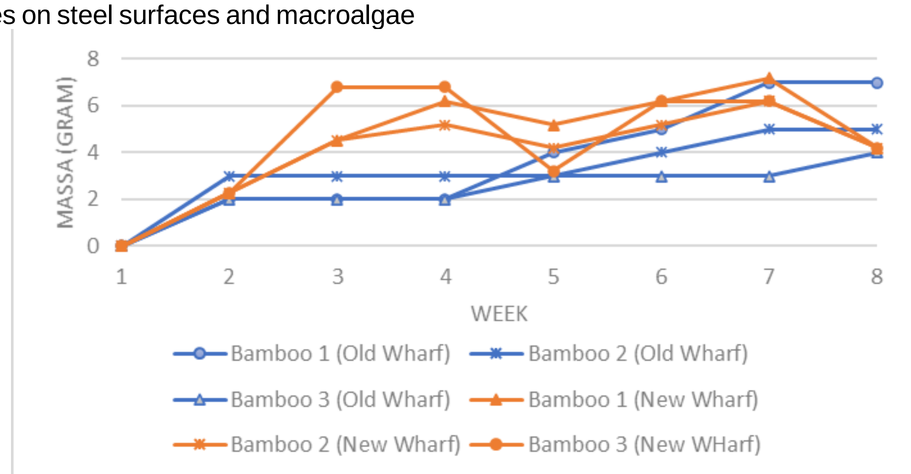


Figure 6. Fouling Mass on Laminated Bamboo

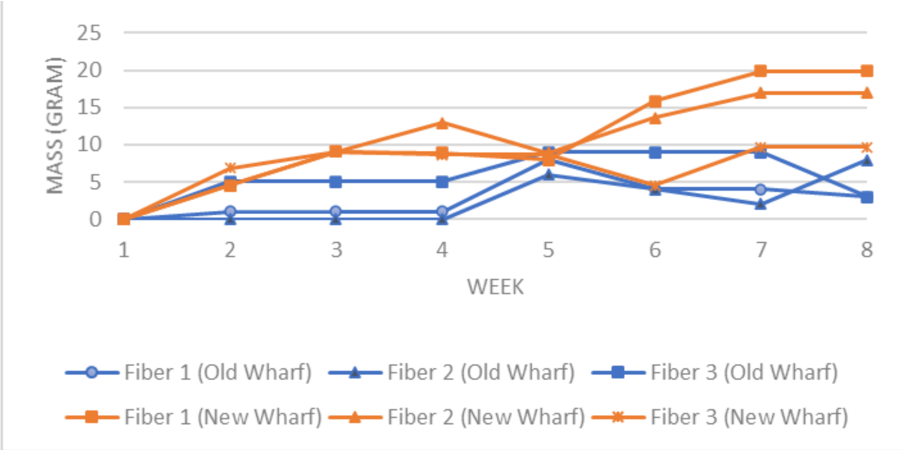


Figure 7. Fouling Mass on Fiberglass

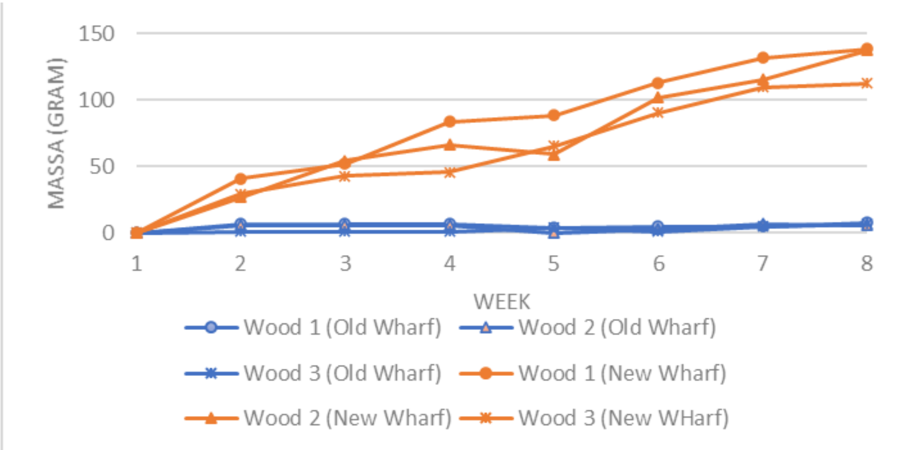


Figure 8. Fouling Mass on Wood

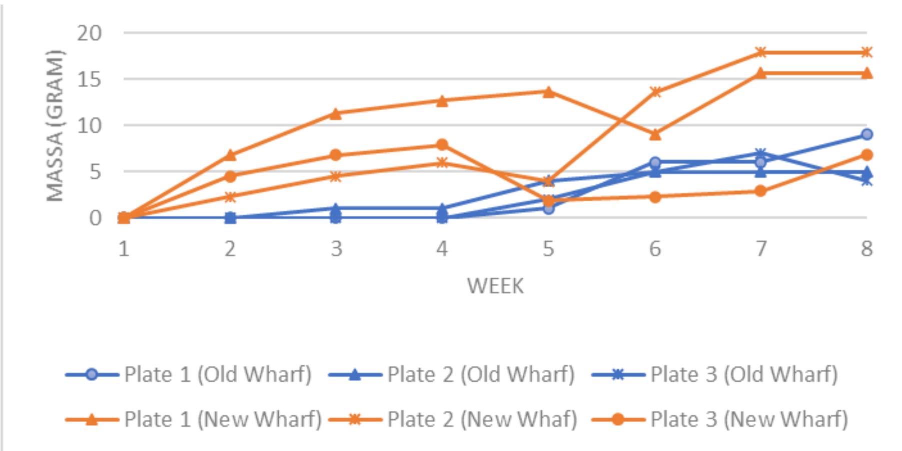


Figure 9. Fouling Mass on Steel ASTM-36

Figures 6 to **Figure 9** are graphics from all materials. Those graphics show that biofouling mass from week to week fluctuated. Many factors that follow in the field. Biofoulers can release when selecting attachment location and choose another substrate as the newly hatched (Chase, 2015). All graphics show that biofouling in new wharf had heavier mass than in old wharf. Numerous differences especially in physical conditions may explain the differences between old wharf and new wharf. Current velocity condition in old wharf was bigger than the new wharf. Current velocity in old wharf and new wharf are 0,5 m/s and 0,2 m/s, respectively. Environmental conditions and properties of the process surface make an effect on fouling formation. A stagnant for low flow allows biofouling growth more easily attach to the surface (Kukulka & Devgun, 2007) so higher flow make lighter biofouling mass. The relation between biofouling growth and environmental conditions is a complex relationship, this is not just current velocity that effect the biofouling growth but seawater surface temperature, salinity, acidity, light intensity, concentration of nutrients, time of the exposure to water, micro-texture of surface, surface potential, the contact angle which is a measure of wettability, and roughness parameter, also surface contour and color have various effect on biofouling growth (Bixler & Bhushan, 2012). A comprehensive biofouling growth model that predicts clearly about biofouling growth rate under varying environmental conditions does not exist. A successful comprehensive biofouling growth model needs significant barriers in the path (Uzun *et al.*, 2019).

Figure 6 to **Figure 9** show there are significant biofouling growth rates at first week. Biofilm development has several stages. Between time and biofilm thickness, there is an idealized biofilm development curve (Melo & Bott, 1997). At the first-time immersion bacteria make a conditioning with mass limit to 0, but after conditioning and initiating of biofilm growth, there is a rapid development in biofilm thickness. After the rapid period, the biofilm thickness becomes stabilized. This rapid development made a significant biofouling growth rate on the graph.

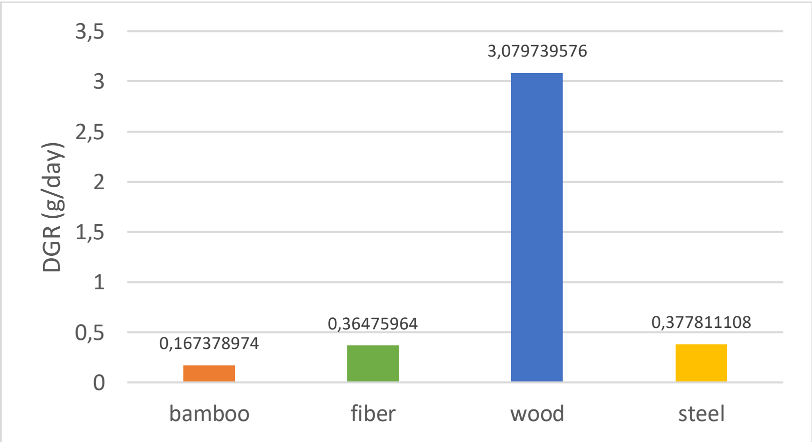


Figure 10. DGR Average of all materials in the new wharf

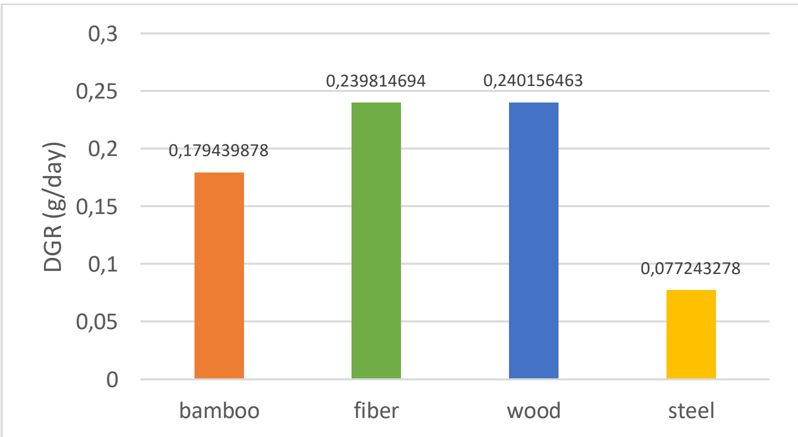


Figure 11. DGR Average of all materials in the old wharf

According to DGR average in **Figure 10** and **Figure 11**, wood had the most biofouling in this research. Biofouling such as *Balanus*, oyster, and *Saccostrea* prefer stick to the wood rather than fiber and steel (Hendra, 2016). Community biofoulant differences result from differential larval settlement on different materials (Chase, 2015). Laminated bamboo tends to have a low DGR value, around 0,17 g/day in all wharf. Bamboo is a complex polymer that consists of Carbon (C), hydrogen (H), oxygen (O), sulfur (S), and nitrogen (N) (Liu *et al.,* 2015). Wood and bamboo have the ability to absorb water which makes these materials as a hydrophilic material. This makes it easier for the larvae of foulers to attach, but bamboo was used in this research is laminated bamboo. Bamboo laminate has a high consistent consistency in the attachment of biofouling. This is possible because this material has toxic properties to marine organisms. Making lamination on this bamboo material is preserved using borax. Strong preservative power of borax comes from the content of boric acid in it. Therefore, the test material is toxic to marine life that will be attached to this material (Hendra, 2016). Lamination also makes a hydrophobic surface that can make the foulers difficult to stick on material (Erfle *et al.,* 2021).

CONCLUSIONS and SUGGESTION

After two months of immersion, there are invertebrates on steel surfaces and macroalgae on wood, laminated bamboo, and fiberglass surfaces. Steel has more variants of macrofouling than others. According to the result, biofouling mass from week to week was fluctuated. physical conditions may explain the differences between old wharf and new wharf. Current velocity condition in old wharf was bigger than the new wharf. Current velocity in old wharf and new wharf are 0,5 m/s and 0,2 m/s, respectively. Environmental conditions and properties of the process surface make an effect on fouling formation. A stagnant for low flow allows biofouling growth more easily attach to the surface. Rapid development of biofilm made a significant biofouling growth rate on the graph. Wood had the most biofouling in this research and laminated bamboo tends to have a low DGR value, around 0,17 g/day in all wharf.

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