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Identification of Marine Borer Species on Ternate Beach, North Maluku, Indonesia

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ABSTRACT

The Ternate coast is a tropical marine area characterized by warm temperatures and high salinity, supporting various marine organisms, including borers that cause wood biodeterioration. These organisms inflict severe damage on wood-based coastal infrastructure, including piers, stilt houses, and vessels. This study aimed to identify marine borer species in Ternate and determine the infested coastal wood types. The research was conducted from March to June 2024 using wood baiting and direct observation methods. The baiting test was performed at Dufa-dufa and Falajawa Beaches using tusam (*Pinus merkusii*) and rubberwood (*Hevea brasiliensis*), assembled according to SNI 7207:2014 and submerged in the sea. Direct observations were carried out across nine beaches in Ternate City by collecting wood samples showing signs of attack. Specimens were preserved in 70% alcohol and identified under a microscope in the laboratory. The study identified four marine borer species: *Bankia carinata* (*Mollusca*), alongside *Chelura insulae*, *Sphaeroma terebrans*, and *Cenoloba obliteralis* (Arthropoda). *B. carinata* infested the bait wood, whereas the other three species were present in wood collected during coastal observations. Damage levels on tusam and rubberwood were higher at Falajawa Beach than at Dufa-dufa Beach. Marine borer activity was supported by aquatic conditions featuring temperatures of 20–31°C, salinity of 30–35 ppt, and pH levels of 7.9–8.4. Infested coastal wood species included mangrove apple (*Sonneratia* sp.), beach calophyllum (*Calophyllum* sp.), and sea hibiscus (*Hibiscus* sp.).

Keywords: bait wood, crustaceans, mollusca, observation

INTRODUCTION

Coastal areas are dynamic ecosystems influenced by oceanographic factors such as temperature, salinity, light intensity, and waves. The Ternate coast is located in a tropical marine region with warm temperatures and high salinity, which supports the development of various marine organisms. These conditions make wooden infrastructure such as piers, stilt houses, ships, and boats vulnerable to degradation caused by marine borers. These organisms are the primary agents of biodeterioration; they bore into wood to use it as a habitat and source of nutrients, thereby damaging the structural integrity from the inside without being detectable from the surface (Turner 1966). As a result, the service life of coastal infrastructure is reduced, and the demand for timber increases.

Marine borers generally belong to the phylum Mollusca, particularly the families Teredinidae and Pholadidae, as well as the phylum Crustacea, which includes the genera *Limnoria*, *Chelura*, and *Sphaeroma*. Various studies in Indonesia have reported the presence of these organisms in several regions, including Rambut Island, Wakatobi, Nusa Lembongan, and Southeast Sulawesi, with diverse species compositions (Muslich & Sumarni 2004; Cookson *et al.* 2012; Diba *et al.* 2021; Ginantra *et al.* 2022; Pujirahayu 2024).

The results of these studies indicate that the distribution and intensity of marine borer infestations are influenced by environmental conditions. Globally, losses caused by these organisms are estimated to reach billions of euros annually (Borges *et al.* 2014), whereas in Indonesia, information regarding species distribution and the types of wood affected remains limited. Furthermore, marine borers have been reported as the primary cause of damage to various wooden structures in coastal environments (Cragg *et al.* 1999). Therefore, this study aims to identify the marine borer species present on Ternate Beach as well as the types of wood infested along the coastline.

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METHODS

Time and Place of Research

Sampling was conducted from March 2024 to June 2024 in the subtidal and intertidal zones of Ternate Beach. Sampling was conducted using the wood baiting method at two main locations: Dufa-dufa Beach in North Ternate Sub-District and Falajawa Beach in Central Ternate Sub-District. Furthermore, observation methods were carried out in five sub-districts covering nine beaches: Falajawa Beach in Central Ternate Sub-District, Dufa-Dufa Beach in North Ternate Sub-District, Sulamadaha, Tobololo, and Tolire Beach in West Ternate Sub-District, Afetaduma, Ake Rica, and Kastela Beach in Ternate Island Sub-District, and Gambesi Beach in South Ternate Sub-District. A map of the research locations is presented in Figure 1. Identification of marine borer specimens was conducted at the Animal Function and Behavior Laboratory, Department of Biology, FMIPA IPB, while identification of wood species infested by marine borers was conducted at the Wood Anatomy Laboratory, Department of Forest Products, Fahutan IPB.

Equipment and Materials

The equipment used included a float, plastic hose, sinker, 1.5 ml tubes, a tube box, tweezers, a digital camera, a binocular microscope, *an* EZ9909 *water quality tester*, and a rope. The materials used consisted of tusam wood (*Pinus merkusii*), rubberwood (*Hevea brasiliensis*), and 70% alcohol. The bait wood measured 2.5 cm × 5 cm × 30 cm, in accordance with Indonesian National Standard (SNI) 7207:2014.

Measurement of Salinity, Temperature and pH of Water

The environmental parameters measured included salinity, temperature, and seawater pH using the EZ9909 Water Quality Tester. Measurements were taken in situ every month during the bait period, which lasted three months.

Collection of Marine Borer Specimens

Specimens of the marine borer pest organisms were collected using bait and direct observation methods. The bait method followed SNI 7207:2014 and was conducted at Dufa-dufa Beach (North Ternate District) and Falajawa Beach (Central Ternate District). Bait logs were arranged according to the research design, with 10 bait-wood samples installed (Wood Feeding) at each bait site, and then soaked for three months. The arrangement of the bait logs is shown in Figure 2. After the bait period ended, the wood was retrieved, cleaned, and inspected for the presence of borer organisms. Specimens found were collected and preserved in 70% alcohol for identification. Subsequently, the bait wood was split to analyze the severity of damage caused by marine borers. The percentage of damage intensity was calculated and classified based on the SNI 7207:2014 standard (Table 1). Additionally, direct observations were conducted at nine beaches in Ternate by collecting wood found near

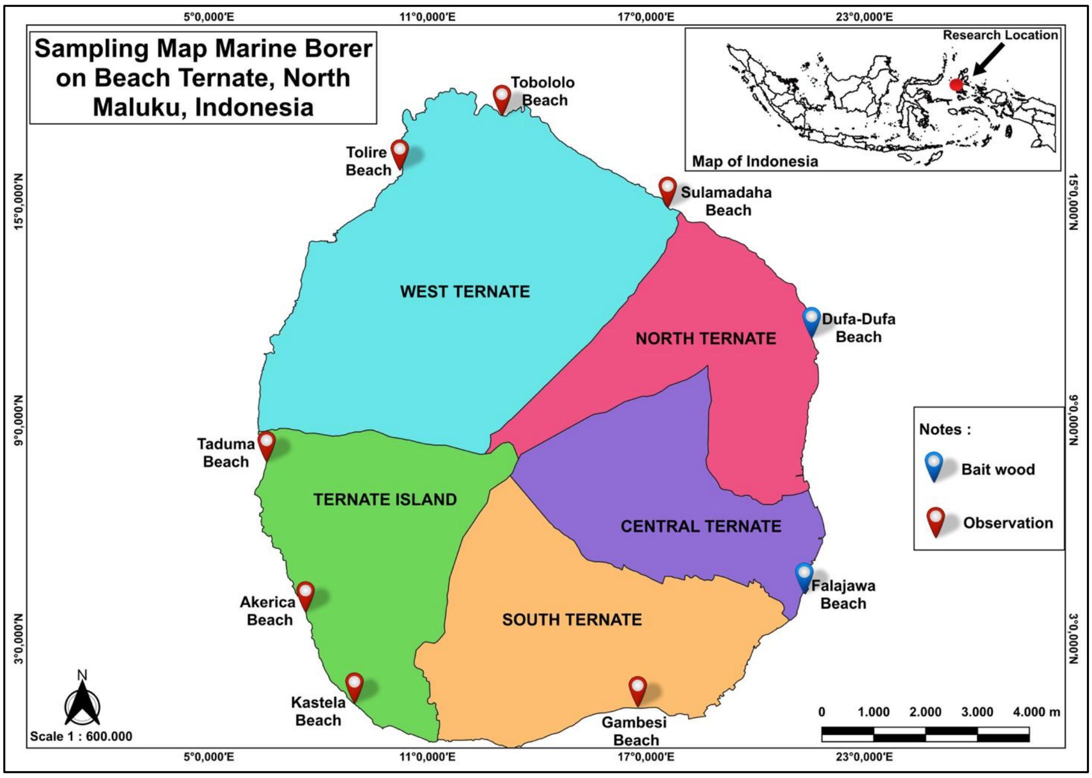


Figure 1 Map of the location of marine borer sampling at Ternate Beach.

the shoreline to examine marine borer attacks, following the method described by Rao *et al.* (2008).

Identification of Marine Borer Specimens and Wood Species Based on Observations

Specimens were examined under a microscope using an identification key based on the methods described by Turner (1966, 1971a, and 1971b). Wood samples infested with marine borers, collected during field observations, were split and examined under a microscope using cross-sections to identify their anatomical structures. Identification was based on general wood characteristics, namely the visual characteristics and macroscopic structure of the wood, in accordance with Indonesian National Standard SNI 8491 (2018).

Data Analysis

Data processing was performed using Excel, ImageJ, and Quantum GIS software. The data were analyzed using descriptive analysis (Sugiyono 2010) to describe the marine borer species found on Ternate Beach based on the specimens collected and the types of wood infested by marine borers.

RESULTS AND DISCUSSION

Marine Borer Species on Ternate Beach

At least four species of *marine borers* have been identified: *Bankia carinata* from the Phylum *Mollusca*, and *Chelura insulae*, *Sphaeroma terebrans*, and *Cenoloba obliteralis* from the Phylum *Arthropoda* (Table 2). *B. carinata* was found infesting bait wood submerged in the sea, whereas *C. insulae*, *S. terebrans*, and *C. obliteralis* were found on observation wood, that is, wood that had been in coastal areas for a long time. The discovery of *B. carinata* in this study is consistent with previous research reporting that the genus *Bankia* is one of the dominant *shipworm genera* in tropical and subtropical waters. Turner (1966) reported that the genus *Bankia* has a wide environmental tolerance, particularly regarding salinity

a) b) c)

Figure 2 Bait for marine borers: a) bait sketch, b) bait wood assembly, c) view of the submerged bait wood.

Table 1 Classification of wood resistance to marine borers (SNI 7207:2014)

Class	Resistance	Infestation Intensity (%)
I	Highly resistant	<7.0
II	Resistant	7.0–27.0
III	Moderately resistant	27.1–55.0
IV	Not resistant	55.1–80.0
V	Highly unstable	>80.0

Table 2 Marine borer species identified through bait and observation at Ternate Beach

Species	Phylum	Wood Type	Method
Bankia carinata	*Mollusca*	Tusam wood and rubberwood	Bait
Chelura insulae	*Arthropoda*	Mangrove apple wood, beach calophyllum wood, and sea hibiscus wood	Observation
Sphaeroma terebrans	*Arthropoda*	Mangrove apple wood, beach calophyllum wood, and sea hibiscus wood	Observation
Cenoloba obliteralis	*Arthropoda*	Mangrove apple wood	Observation

and temperature, and is therefore frequently found infesting wood submerged in the sea.

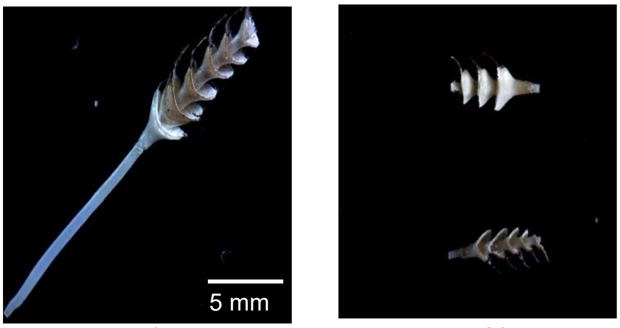
The water conditions off the coast of Ternate are characteristic of tropical waters, with water temperatures ranging from 20°C to 31°C, salinity ranging from 30 ppt to 35 ppt, and a pH ranging from 7.9 to 8.4 during the three-month observation period. According to Effendi (2003), these environmental parameters fall within the optimal range for tropical marine waters and support the survival and activity of marine biota. Relatively stable temperature, salinity, and pH conditions support the growth, metabolism, and activity of marine wood-boring organisms, including the families *Teredinidae* and *Crustacea* (Cragg 2015).

The species *B. carinata* is a shipworm belonging to the Phylum *Mollusca*, family *Teredinidae*, which has an elongated, worm-like body and feeds by boring into wood submerged in seawater, such as ships, wooden beams, and mangroves. Its body terminates in two siphons, and at the tip of each siphon is a protective structure (pallet) shaped like a stacked cone and lined with *a periostracum* (Turner 1966). The distinctive shape of *the pallet* is a key characteristic for species identification. Although the body *of B. carinata* is embedded within the wood, *the pallet* remains visible on the surface, serving as a plug for the hole when the siphons are retracted. In this study, the bodies of the species were not found due to constraints during sample collection; therefore, identification was based solely on *the pallets* (Figure 3).

The wood-boring mechanism of *B. carinata* involves using a small shell on the anterior part of its body. After entering the wood, the organism continues to bore until it forms a tunnel that serves as a habitat and breeding ground. According to Turner (1966), this process begins when the larva of *B. carinata,* having undergone metamorphosis into a juvenile, attaches itself to the wood surface and then scrapes away wood fibers through the rotational movement of its shell, driven by muscle contractions. Once inside the wood, *B. carinata* secretes a layer of calcium carbonate on the tunnel walls to protect its body (Nair 1966; Voight 2015). The tunnel length can reach 320 mm, while the boring rate is influenced by wood type, temperature, salinity, and food availability.

The species *C. insulae* (Figure 4) is an amphipod of the family *Cheluridae* that inhabits wood in coastal areas. Its body is cylindrical and consists of flat segments, each covered with fine hairs (setae). Its body length ranges from 5–10 mm, and its width from 2–5 mm. According to Habtemariam (2016), *C. insulae* is able to adapt to the dynamic intertidal zone environment, which frequently undergoes physical and chemical changes due to the influence of tidal fluctuations. The fine hairs on its body function as sensory organs and aid in its movement within the wood tunnels it inhabits.

C. insulae attacks by boring into the wood surface using its strong, sharp mandibles, creating holes and tunnels within the wood that reduce its structural



a) b)

Figure 3 The *Bankia carinata* species found on bait wood a) pallet shape, b) inner and outer sections of the pallet.

Figure 4 *Chelura insulae* specimen during observation of wood.

strength. The boring activity of *C. Insulae* causes mechanical damage in the form of cracks and the breaking of wood fibers, thereby accelerating the degradation process (Palma & Santhkumaran 2014). In Indonesia, *C. insulae* is reported to have a limited distribution, primarily in the mangrove areas of Kalimantan (Suharsono 2014). This organism is also associated with bacteria and fungi that break down cellulose and lignin, thereby increasing the wood's susceptibility to attack.

The species *S. terebrans* (Figure 5) is a crustacean belonging to the family *Sphaeromatidae*. This species is known for its ability to attack wood, particularly waterlogged wood, wood used in bridge construction, and other wooden structures exposed to water. *S. terebrans* has a segmented, convex, and elliptical body. It measures 8-12 mm in length and ranges in color from brown to reddish-brown. This species often curls into a ball when threatened (Hossain 2013). Previous research on *S. terebrans* has identified its presence in the mangrove forests of Kutai Kartanegara, East Kalimantan (Harmonis *et al.* 2024).

S. terebrans attacks wood by boring into the wood's surface using its powerful mouthparts (mandibles). This organism has sharp *mandibles* and is capable of effectively scraping away the outer layer of wood. This process begins with the organism attaching itself to the wood surface and gradually boring into the wood. According to Rotramel (1975), *S. terebrans* is capable of creating holes with a diameter of about 2–3 mm and a depth of several centimeters, depending on the condition of the wood and the environment. After successfully penetrating the wood's surface, *S. terebrans* forms tunnels or galleries inside the wood. These tunnels serve as a dwelling and shelter for the organism. Kussakin (1973) states that the tunnels created by *S. terebrans* are often branched and interconnected, causing the wood to become brittle and lose its structural strength.

The species *C. obliteralis* (Figure 6), belonging to the class *Insecta*, attacks wood, particularly dead mangrove wood in coastal areas. This finding aligns with the report by Ginantra *et al.* (2022) from Nusa Lembongan, Bali, who also found *Cenoloba* larvae infesting the trunks of dead *Sonneratia alba* trees. The similarity of these results strengthens the evidence that *Cenoloba* has a fairly wide distribution and plays a role in the decomposition of mangrove wood in Indonesia.

C. obliteralis larvae are caterpillar-like (*eruciform*), elongated, cylindrical, segmented, measuring 8–12 mm, with a body ranging in color from yellowish-white to pale cream and a dark brown to black head capsule. The larvae have strong mandibles for boring into wood and move using their thoracic legs and *prolegs* within the tunnels they create. This boring activity produces fine wood dust (*frass*) and creates tunnels in dead mangrove trunks, causing discoloration of the wood, weakening of the tissue, and increased brittleness of

a) b)

Figure 5 *Sphaeroma terebrans* specimens found during wood observations: a) inner part, b) outer part.

a) b)

Figure 6 Cenoloba obliteralis specimens found during wood observations: a) outer larva, b) inner larva.

the trunk. Abu (2019) reported that *C. obliteralis* also attacks *Sonneratia alba* and *Avicennia marina* in Saudi Arabia, causing damage characterized by the formation of tunnels. Research by Jenoh *et al.* (2016) in Kenya also showed that *Cenoloba* species, along with the beetle *Bottegia rubra*, cause damage to *S. alba*, with infestation rates reaching 18–25% of the stand.

Identification of Damage to Bait Wood Infested by Marine Borers

The results of bait wood trials at two locations revealed differences in the level of marine borer infestation. At Falajawa Beach, the intensity of damage to the bait wood reached 60.8% (Figure 7), indicating high activity of marine borers. The relatively stable, unpolluted water conditions, along with good physical and chemical water quality, support the colonization and development of marine borers. In contrast, no infestation was found at Dufa-Dufa Beach during the observation period, presumably due to oil pollution from ship activities and domestic waste from coastal communities. According to Effendi (2003), oil pollution and organic waste degrade water quality, disrupt the respiration and metabolism of marine organisms, reduce dissolved oxygen levels, and alter substrate characteristics, thereby making the environment less suitable for marine borers.

The susceptibility of tusam wood has been reported by Eriksson (1990), who stated that tusam wood, as a softwood species, has low resistance to marine borers. This is due to its high cellulose and hemicellulose content, which serves as the primary food source for *Teredinidae*. Muslich and Rulliaty (2004) state that tusam wood belongs to the class of wood most susceptible to marine borer organisms such as *Bankia* spp. A study by Nair (2012) on the vulnerability of rubberwood (*H. brasiliensis*) explained that although rubberwood contains natural latex, its low lignin content (approximately 25%) makes it easily degraded by boring organisms. Research conducted by Borges *et al.* (2014) showed that *H. brasiliensis* in tropical waters suffered serious damage caused by *B. carinata* within six months, with an average of 50 to 70 holes on the wood's surface.

Wood Species Affected by Marine Borers: Results of Observations

Based on the identification of wood infested by *marine borers* through observation, at least three types of wood were identified: mangrove apple (*Sonneratia* sp.), beach calophyllum (*Calophyllum* sp.), and sea hibiscus (*Hibiscus* sp.). The condition of the wood found indicated a fairly high level of damage caused by marine wood-destroying organisms (Figure 8).

Sea hibiscus wood suffered very severe damage, indicating that although this wood species is traditionally used to build boats or structural components in coastal areas, its durability is actually limited when exposed to coastal environments for extended periods or on a permanent basis. This is consistent with test results from Rambut Island, which showed that most light to medium density wood species, including *hibiscus*, cannot withstand attacks for more than six months (Muslich & Sumarni 2004).

Macroscopic Analysis of Wood

Based on observations of wood samples collected during the fieldwork, the wood can be identified based on visual and macroscopic characteristics, taking into account the anatomical features that distinguish one species from another (Table 3).

Mangrove apple wood is an important component of Indonesia's mangrove ecosystems. According to Giesen *et al.* (2007), this tree thrives in the foreshore zone of mangrove forests that directly border bodies of water. The macroscopic structural characteristics of mangrove apple wood (*Sonneratia* sp.) (Figure 9) show

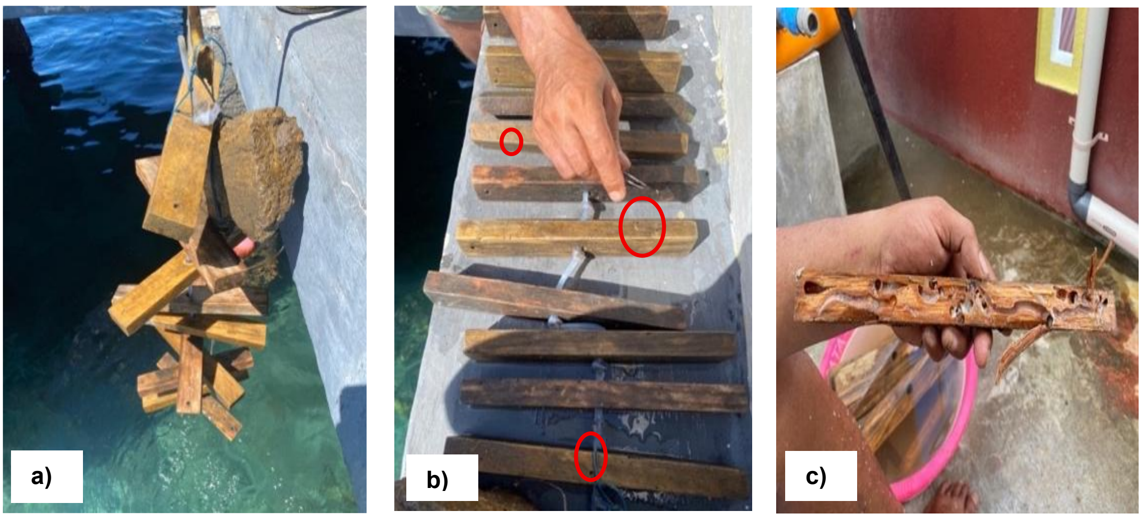


Figure 7 *Bankia carinata* infestation on bait wood: a) collection of bait wood specimens, b) small holes on the surface of the bait wood, c) borer holes inside the bait.

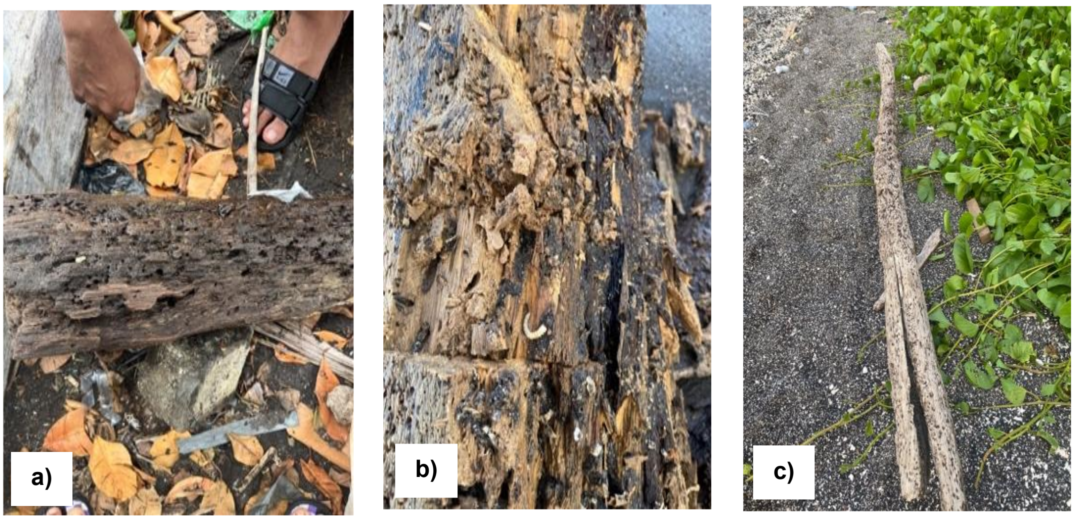


Figure 8 Marine borer infestation in wood based on observation a) sea hibiscus wood, b) mangrove apple wood, c) beach calophyllum wood.

Table 3 Visual characteristics of wood found to be infested by marine borers

Species	Color	Pattern	Texture	Grain direction	Luster	Tactile feel	Hardness
Sonneratia sp.	Yellowish brown	Straight	Smooth	Straight	Dull	Slightly slippery	Soft
Calophyllum sp.	Light brown	Straight	Smooth	Straight	Dull	Smooth	Hard
Hibiscus sp.	Light brown	Straight	Smooth	Straight	Dull	Slightly slippery	Soft

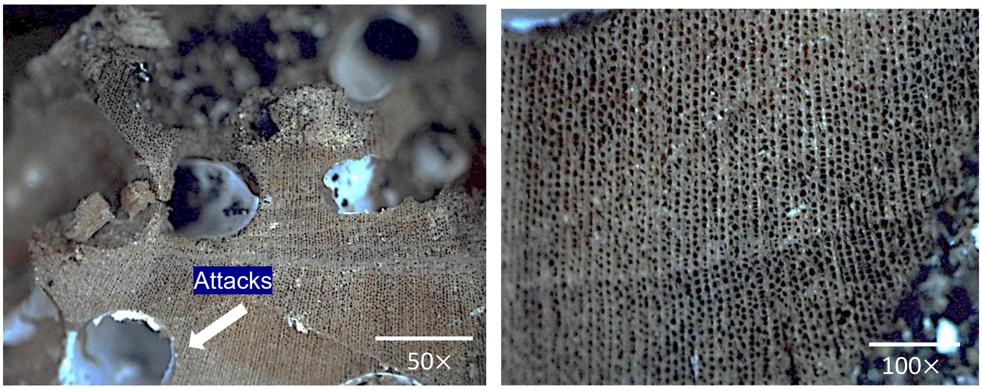


Figure 9 Macroscopic structure of mangrove apple wood a) infestation by *Sphaeroma terebrans* and *Cenoloba obliteralis*, b) cross-sectional view of mangrove apple wood.

growth rings that are not clearly visible during identification because the wood had been exposed near the shoreline for a long time and had undergone weathering.

The vessel cell region (pores) exhibits a diffuse-porous pattern, dominated by solitary pores with some radially joined in groups of 2–3 cells. Axial parenchyma is very rarely found, while the wood rays are relatively uniform. Intercellular channels extend tangentially, forming fine lines. Although it grows in a marine environment, mangrove apple wood has low natural resistance to attacks by *marine borers* such as *Teredo navalis*. Unlike *Rhizophora* wood, which is rich in tannins and silica, mangrove apple wood is more susceptible to boring and damage when submerged, resulting in reduced service life and structural strength. Therefore, without preservative treatment, mangrove apple wood is not recommended for maritime construction requiring high durability (Eaton & Hale 1993).

Beach calophyllum wood is an oil-producing hardwood (*bintangor oil*) that grows in tropical coastal regions, including Indonesia. The tree can reach a height of 30 m with a trunk diameter of up to 1.5 m. This wood has heartwood ranging in color from reddish-brown to dark brown, with paler sapwood; it is classified as strength class II-III and durability class II (Martawijaya *et al.* 2005). The macroscopic structure in the cross-section (Figure 10) shows indistinct growth rings due to weathering and attack by marine borers. The pores are of the diffuse-porous type, predominantly solitary with some radially joined in groups of 2–3 cells; they are medium to large in size and mostly contain tyloses. Axial parenchyma is very rare; the wood rays consist of short, wide, and long, narrow types, while the intercellular channels are arranged radially within the wood rays.

Sea hibiscus wood is a type of wood from the Malvaceae family that is commonly found in tropical coastal areas, including Indonesia. Its macroscopic structure (Figure 11) shows indistinct growth rings due to the wood having been exposed to the coast for a long time and having suffered an attack by *marine borers*. The pores are of *the diffuse type*, predominantly solitary, quite numerous, but rarely contain tyloses. Axial parenchyma is scattered around the vessels, forming an aliform pattern, while the wood rays consist of two sizes with no striking differences and contain extractives. Intercellular channels are arranged radially within multiseriate rays.

(The water conditions) In general, the high level of damage to these three wood species can be attributed to tropical aquatic environmental factors that support the life cycle of marine borer organisms, particularly in areas with an average temperature of 28–30°C and salinity of 30–33 ppt, such as the waters off the northern coast of Java (Muslich & Sumarni 2004). Wood that is continuously exposed to the marine environment experiences a gradual decline in strength and integrity due to boring activity that creates cavities and tunnels within the wood tissue. A statement by Cragg *et al.* (2007) confirms that no type of wood is completely resistant to marine borer attacks without special protection or treatment, especially if it is exposed to open waters for an extended period.

CONCLUSION

At least four species of marine borers were found on Ternate Beach: *Bankia carinata* (Phylum *Mollusca*), as well as *Chelura insulae*, *Sphaeroma terebrans*, and *Cenoloba obliteralis* (Phylum *Arthropoda*). Species from the Phylum *Mollusca* were found in the bait wood, while those from the Phylum *Arthropoda* were found in the observed wood. At least three types of wood from the observations were found to be infested by *marine borers*: mangrove apple wood (*Sonneratia* sp.*)*, beach calophyllum (nyamplung) wood (*Calophyllum* sp.), and sea hibiscus (waru) wood (*Hibiscus* sp.).

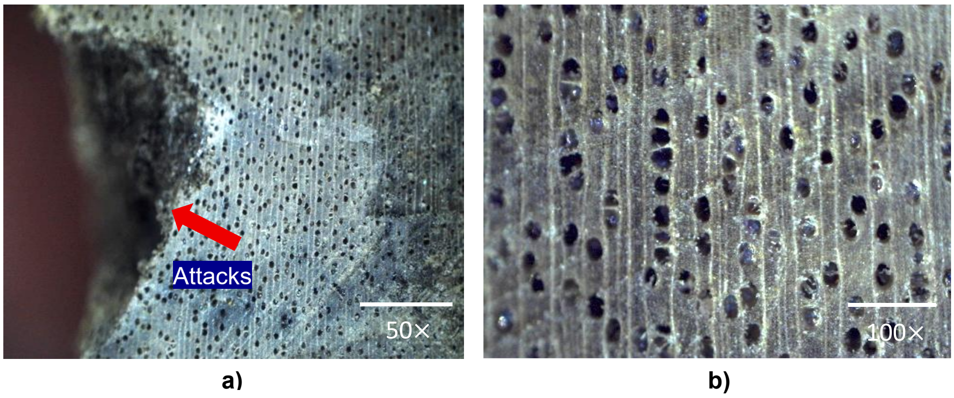


Figure 10 Macroscopic structure of beach calophyllum wood a) damage caused by *Chelura insulae*, b) cross-sectional view of beach calophyllum wood.

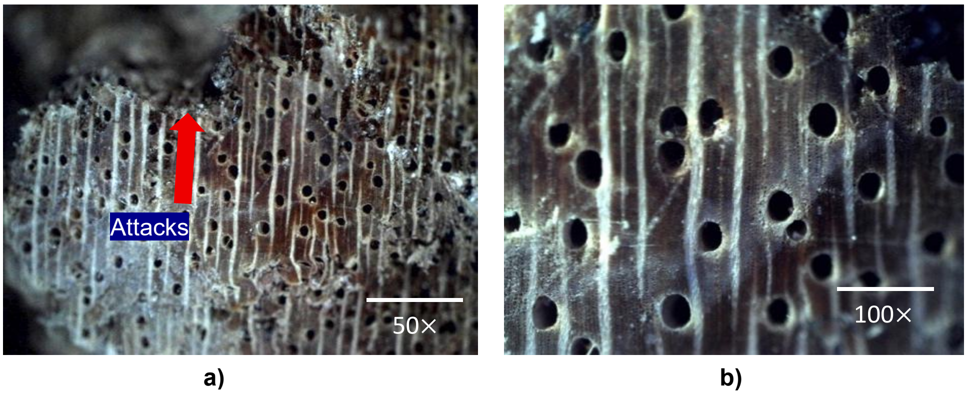


Figure 11 Macroscopic structure of sea waru wood a) attack by *Chelura insulae*, b) cross-sectional view of sea waru wood.

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